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R.H. SAUNDERS GS
1988 INSTRUMENTATION INSTALLATIONS

Report No 91-134-K

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ABSTRACT

New instruments installed in R.H. Saunders GS as part of the 1988 Dam Safety Program are described and their initial readings are documented. These instruments include two normal pendulums, two inverse pendulums, crack meters and multilevel groundwater sampling equipment. The inverse pendulums are noteworthy as being the deepest installations by Ontario Hydro to date. New optical readout devices have been incorporated in the pendulum installations to improve the speed, accuracy and repeatability of readings.

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To Mr. O. Bernaus
Manager
Civil Maintenance
Hydraulic Generation Group

R.H. SAUNDERS GS
1988 INSTRUMENTATION INSTALLATIONS

1.0 INTRODUCTION

R.H. Saunders GS with an installed capacity of 942 MW is the second largest power producer in Ontario Hydro's hydraulic system. Completed in 1958, the concrete Main Dam has a maximum height of 154 feet and a crest length of 1560 feet. Together with an 18,500 foot long earth dyke on the Canadian side and similar structures on the American side of the St. Lawrence River, the Main Dam retains a reservoir some 27 miles long and up to 7 miles wide/1/. The Town of Cornwall is located immediately downstream of this structure on the Canadian side causing it to be rated as a high hazard structure.

It is common practice, worldwide, to instrument structures of this importance for seepage, uplift pressures and deformation/2/. Indeed, drainage monitoring systems and uplift cells were installed with the original construction. But until recently, regular deformation monitoring for dam safety purposes was virtually non-existent. Survey monuments were installed for a high accuracy control survey in 1985. Additional monuments were installed on the earth dyke in 1987 and on the concrete main dam in 1988 to strengthen the control network and to tie this external survey to monitoring inside the dam. While the survey provides useful information on the external deformation of the Main (concrete) Dam, monitoring of the internal deformation behaviour of this structure was still lacking and needed. Long longitudinal cracking of floors and walls inside the structure/3/, oval deformation of the turbine throat rings and a build up of stress in the structural concrete/4/ indicate that internal structural deformation has taken place. A set of joint meters, installed in 1969 in the upstream and downstream areas of the powerhouse, confirm that progressive bowing of the dam has taken place over the past 20 years/5/. While this movement has not yet impacted the structural integrity of the dam/3/, it has produced diminished mechanical and electrical clearances in the turbines and generators requiring ongoing major corrective maintenance. Alkali-aggregate reactivity, concrete creep, dissolution of the foundation rock and movement along a fold structure underlying the dam have been cited as possible causes of the above maintenance problems. Normal and inverse pendulums were proposed in 1987 and 1988/6,7/ to tie the external deformation survey to internal movements of the dam and

its rock foundation. Installation details and initial readings for these pendulums are documented in this report. Crack meters and multilevel piezometers incorporated into the 1988 instrumentation program are also documented.

2.0 INSTRUMENT LOCATIONS

The 1988 instrumentation program consisted of:

- 2 normal pendulums
- 2 inverse pendulums
- 28 crack or joint gauges
- 2 multilevel piezometers
- 3 survey monuments

As shown in Figures 1 and 2, the normal pendulums are located above the upstream Main Dam inspection tunnel (S4 level) at chainages 20+61.5 and 26+18.5. The inverse pendulums are located below the inspection tunnel at chainages 20+63.5 and 26+15, immediately beside the normal pendulums. As shown in Figure 3 and listed in Table I, the crack meters were installed (a) in the walkway upstream of the units on the S1 level, (b) in the cable tunnel downstream of the units on the S1 level. The multilevel piezometers were installed in two existing boreholes located in the adit on the S4 level between the elevator and the upstream inspection tunnel. Concrete survey monuments were installed on the crest of the dam adjacent to each normal pendulum and near the Canada/United States border.

3.0 INSTRUMENT INSTALLATION DETAILS

3.1 Normal Pendulum

Using NQ size coring equipment, the two normal pendulums were drilled from the dam deck (elevation 256 feet) to a depth of 121 feet to intersect the roof of the inspection tunnel near the upstream wall. Precise drilling procedures developed by Hydro Quebec/8/ were used to keep this hole plumb within +/-0.25 inch. Figures 4 and 5 show the vertical alignment of the two normal pendulum holes, as drilling progressed, and the depths at which alignment corrections were made. A large number of corrections were required, particularly at chainage 20+61.5 where nine were made, due to frequent intersection of reinforcing bars during the drilling. The upper ends of the normal pendulums are recessed below the dam deck and sealed with a cover plate to prevent ingress of water from rain or snow melt (Figure 6). NQ steel casing, suspended from this top unit, acts as a sleeve through the concrete to protect the pendulum wires from water entering through the construction joints. Rainguards were attached to the NQ casing protruding below the inspection tunnel ceiling to channel any water inflow away from the reading tables (Figure 7). Initial readings are presented in a later section of this report.

3.2 Inverse Pendulums

The two inverse pendulums were drilled below the inspection tunnel (elevation 126) using the drilling techniques described above for the normal pendulums. These installations differed from previous installations/9,10,11,12,13,15,16/ in two ways: first, these were the deepest pendulums drilled to date and, second, these holes were pressure grouted at various stages during the drilling process to control water inflows. At chainage 20+63.5, five corrections were required to keep the hole in alignment during drilling to 170 feet deep (Figure 8). This hole was grouted twice prior to pendulum installation - first, when drilling had progressed to 80 feet and, second, when the hole was complete to 170 feet - to seal the hole against water inflow. Due to frequent soft layers in the rock at 26+15, nine corrections were required during drilling to the final depth of 138 feet (Figure 9). This hole was grouted three times - at 53 feet, at 120 feet and upon completion of drilling - to seal the hole against water inflows prior to placing the pendulum casing. Cement grout was used to seal fractures in the rock during and on completion of drilling and for final installation of the inverse pendulum casings. Details of the grout mixes used and the amount of grout intake in each hole are given in Appendix A.

The core obtained from the inverse pendulum holes was examined by Geotechnical and Hydraulic Engineering Department (G&HED) personal and found to exhibit the same marker beds at levels consistent with other borings on this site (Figure 10). Bedrock was encountered below 17 feet of concrete at 26+15 and below 30 feet of concrete at 20+63.5. A layer of old grout infill was found above marker bed 7 in one hole. Water bearing zones were encountered at depths of 38 feet and 120 feet in the 26+15 inverse pendulum and at 62 feet in the 20+63.5 inverse pendulum. Details of the core logging done by G&HED/17/ are presented in Appendix B.

New reading equipment and initial readings are presented in a later section of this report.

3.3 Crack Gauges and Joint Meters

Alternate construction joints on the S1 level were equipped with joint meters in 1969 and have been monitored since that time. This past work/5/ showed total movements in the 0.040 to 0.070 inch range over 20 years. Twenty eight stainless steel gap gauges (Figure 11) of similar construction to the existing gauges were installed to extend this monitoring to the remaining construction joints and significant cracks within the structure. Sixteen of the new gauges are on joints and twelve are on cracks. Table I lists the new gauges locations and Figure 3 shows their position within the structure.

3.4 Multilevel Piezometers

Waterloo multi-level piezometers were installed in previously drilled HQ boreholes SM-1 and SI-1 located in the elevator to inspection tunnel adit (Figure 12). Two levels in each borehole were isolated by upper and lower chemical packers for water sampling and

pressure monitoring. These levels, consisting of the rock to concrete contact and a water bearing seam lower in the rock, are listed in Figure 12. A manufacturer's technician was employed in the assembly and installation of these units. Due to the artesian flow in these holes (2 to 6 gpm) and the low water temperature (<5°C), the chemical packers took several days to seal. Minor leakage was still present more than one month later so a floor flange, gasket and 0-ring assembly was added to complete the seal at floor level. Each piezometer was outfitted with valves and pressure gauges for uplift monitoring (Figure 13).

3.5 Survey Monuments

Three survey monuments were added to the survey network in 1988. These monuments are located on the crest of the concrete dam (a) between Units 5 and 6, (b) between Units 12 and 13, and (c) between Units 15 and 16. The first two monuments are in close proximity to the suspension points for the normal pendulums. The last point is near the international boundary. All monuments consist of concrete pillars anchored into the deck concrete and are equipped with an invar forced centering target plate.

4.0 PENDULUM MONITORING

As at previous sites, the pendulum reading tables were equipped for depth micrometer readings (Figure 14). Decals were placed on the table surfaces to aid in microlevel placement (Figure 15). Accurate micrometer readings depend on the operator accurately determining when the micrometer contacts the pendulum wire without displacing it. The tables at R.H. Saunders GS were insulated to permit use of electrical contacts to assist reading accuracy. This method has been used with some success at Mountain Chute GS. A new Hüggenberger coordiscope was obtained to read the wire positions optically. Figure 15 shows the mounting bracket for this device. Figures 16 and 17 show x and y readings being taken with the coordiscope. To ensure the coordiscope remains in calibration, a reference station (Figure 18) was installed in the inspection tunnel near the 20+60 pendulums (Figure 19, background).

Initial readings on all the pendulums and autocentering readings on the inverse pendulums (Figure 20) were taken with both devices - micrometer and coordiscope. An autocentering survey was also performed on the normal pendulum holes using micrometer readings only. These measurements were performed during installation in November and December of 1988 and during a call back inspection in April of 1989. Appendix C contains one set of autocentering readings on each normal pendulum. These readings were done to provide assurance that the pendulum wires hang freely and are not in danger of contacting the hole walls. Maximum deviation from casing plumb was about 0.3 inch for chainage 20+61.5 and 0.35 inch for chainage 26+18.5 indicating that adequate clearance had been obtained. As there is some air gap between the steel casing and the concrete drill hole, these readings are not an accurate measure of the hole alignment and are not a good indicator of dam deformations unless movement exceeding the concrete to steel gap occurs.

Appendix D summarizes all reference readings made on the inverse and normal tables in November 1988, December 1988 and April 1989. Significant fluctuations occur in these readings, particularly in the upstream/downstream (N/S) direction. The fluctuations are believed to be driven by the annual thermal cycle and appear to be consistent with this type of movement from cursory observation. However, more readings and a more thorough analysis should be done to confirm this theory.

Autocentering readings on the inverse pendulums are detailed in Appendix E. Multiple sets of readings were performed to assess the accuracy, speed and repeatability of the manual and optical reading methods. The manual method is, not surprisingly, slower because of the need to read from four sides and to touch the wire to take each reading whereas the optical reading method reads from two sides only and does not touch the wire. More repeatable readings were obtained by the optical method. The ability to read without moving the wire and to target accurately because the device provides a magnified view of the wire are probably the key reasons the optical method performs better. The optical readout does have one drawback: it lacks the manual readout feature of checking readings against the table constant for errors. Graphical comparisons of the various autocentering reading data sets are contained in Appendix F. Comparisons of the manual readings (micrometer) versus the table constant show a reading accuracy of +/- 0.010 with the poorer overall accuracy being attributed to the lower part of the hole. Readings obtained by micrometer (manual) compare within +/- 0.020 inch of the optical (coordiscope) readings in the upper 100 feet of both inverses. The comparison deteriorates rapidly below that depth. Repeat sets of manual and optical readings were done to gauge the repeatability of each reading method. The manual sets repeated within +/- 0.030 inch in the upper part of inverse 20+63.5 while the optical sets repeated within +/- 0.010 at inverse 26+15.

For performing comparisons of inverse autocentering data, the most repeatable data was obtained by using the collar reading (also called the floor or zero depth reading) as the reference rather than the table (or reference) reading. Graphs showing the good match obtained for 3 optical data sets and two directions in the two inverse holes are shown in Appendix F.

5.0 SUMMARY

A detailed account of the instruments installed is documented in this report. The instruments installed, in summary, were two normal pendulums, two inverse pendulums, crack meters, and multilevel groundwater sampling equipment. A long-term monitoring program of these instruments will provide valuable data for analysis at the site.

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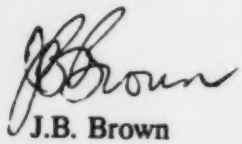
(d) R.H. Saunders machine shop personnel for their timely services and assistance in fabrication.

(e) Mr. B. Jeppesen and Mr. B. Williams, Rock Sciences Section, and Longyear Drilling Company for the quality drilling performed on the normal and inverse holes.

(f) The cooperation of staff in the Civil Works - Maintenance, Civil Works - Dam Safety and G&HED sections in coordinating this work with other concurrent bedrock investigations on site was appreciated.

Approved by:



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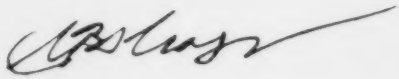

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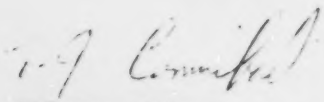

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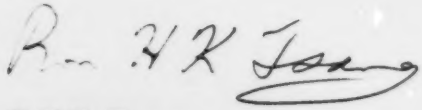

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TABLE I

R.H. Saunders GS
New Crack Meter Locations - 1988

(A) S1 LEVEL: WALKWAY UPSTREAM OF UNITS

Upstream Face of Walkway

1. opposite pillars G4-G5 (S1-1)
2. opposite pillars G5-G6 (S1-2)
3. opposite pillars G10-G11 (S1-3)
4. opposite pillar G13 (S1-4)

Downstream Side of Walkway

1. between pillars G2-G3 (JM31)
2. between pillars G4-G5 (JM29)
3. between pillars G6-G7 (JM27)
4. between pillars G8-G9 (JM25)
5. between pillars G10-G11 (JM23)
6. between pillars G12-G13 (JM21)
7. between pillars G14-G15 (JM19)

(B) S1 LEVEL: CABLE TUNNEL (upstream face)

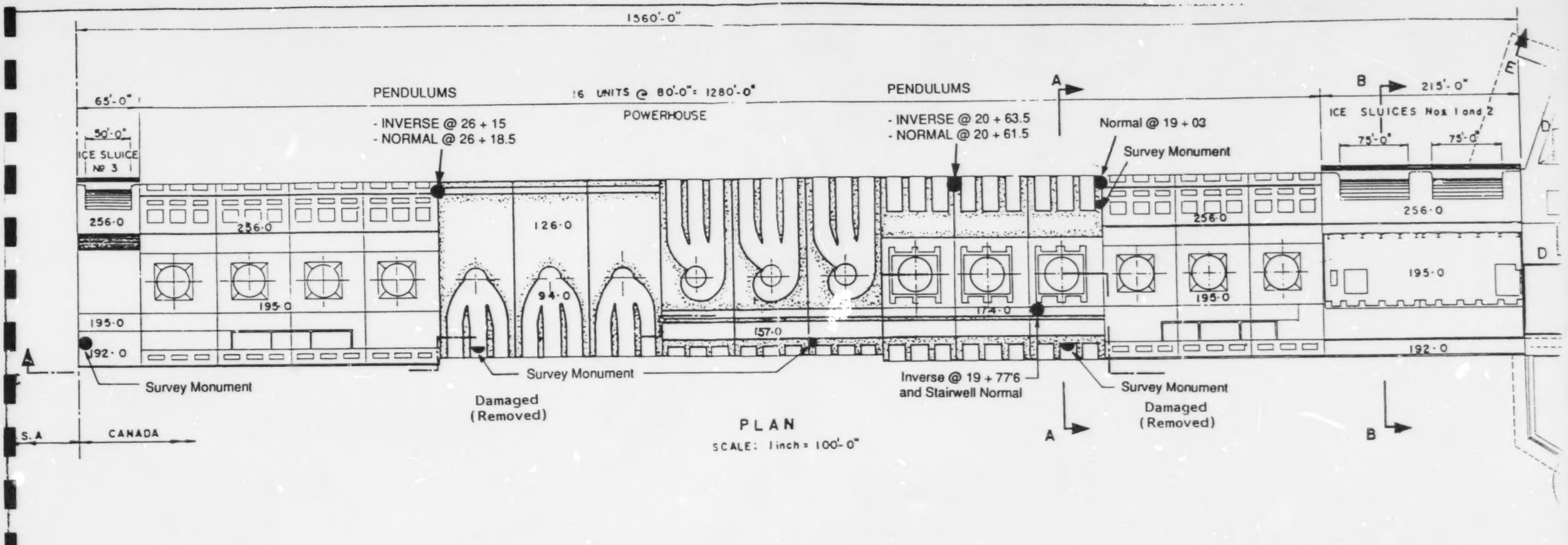
1. between blocks G1-G2
2. between blocks G3-G4
3. between blocks G5-G6
4. between blocks G7-G8
5. between blocks G9-G10
6. between blocks G11-G12
7. between blocks G13-G14
8. between blocks G15-G16

(C) S4 LEVEL

1. In the adit between the elevator and the upstream inspection tunnel (three locations: S4-3, S4-4, S4-5).

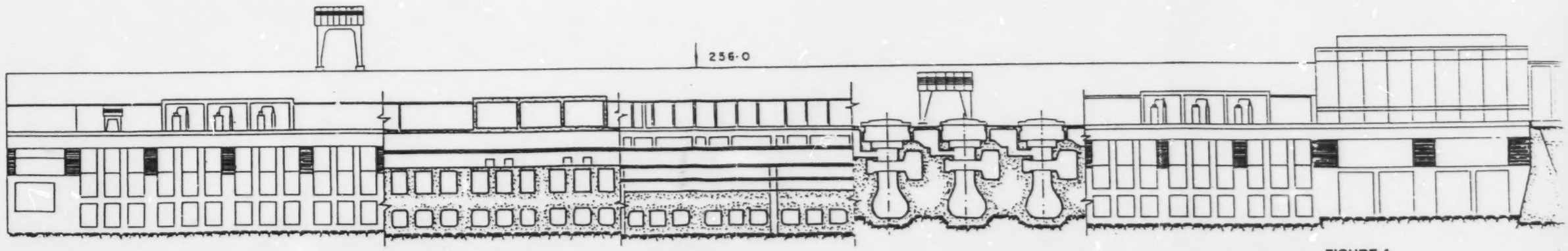
2. In the adit between the inspection tunnel and the closure structure (two locations: S4-1, S4-2).

3. In the adit between the drainage gallery and the inspection tunnel (three locations: S4-6, S4-7, S4-8).



PLAN

SCALE: 1 inch = 100'-0"



ELEVATION. C - C

SCALE: 1 inch = 100'-0"

This information taken from DWG. No. 254-e-77 sheet 4

FIGURE 1

**PLAN & SECTION OF R.H. SAUNDERS G.S.
SHOWING PENDULUM LOCATIONS**

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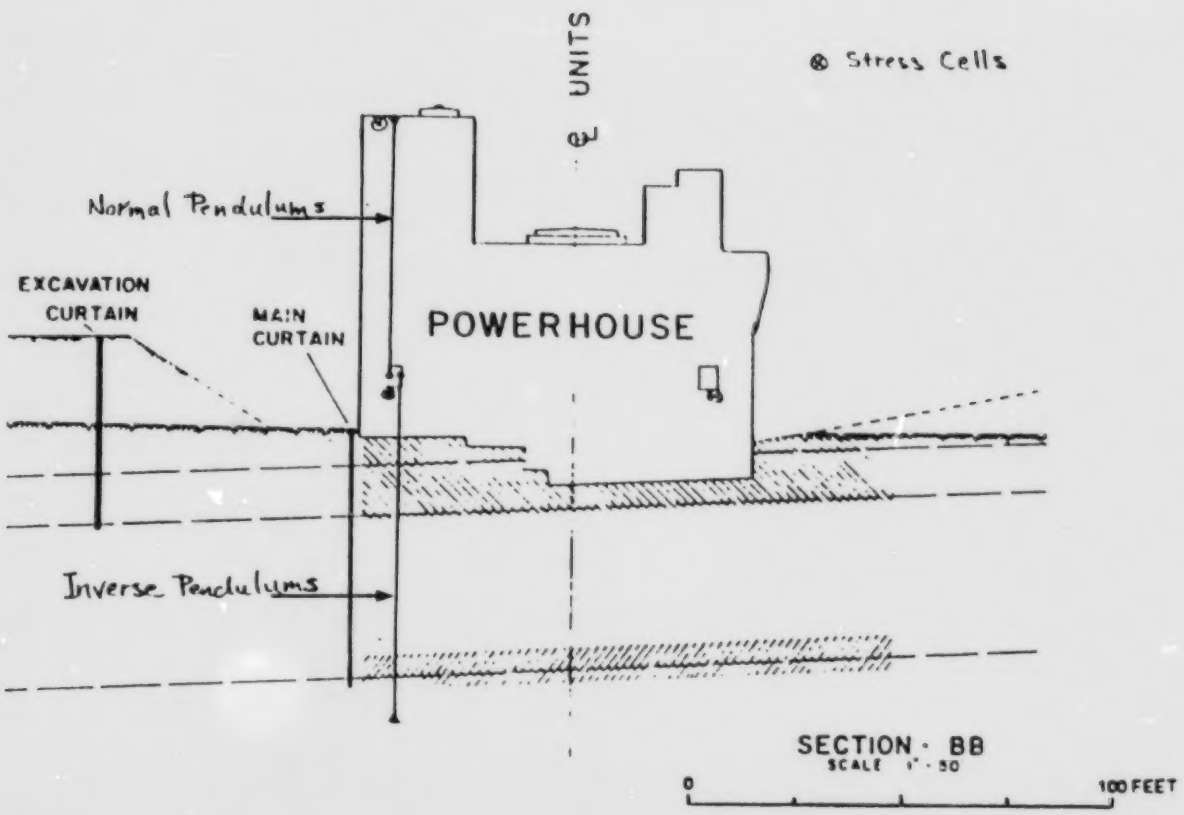


FIGURE 2

SAUNDERS G.S. - CROSS SECTION SHOWING PROPOSED INSTRUMENT LOCATIONS

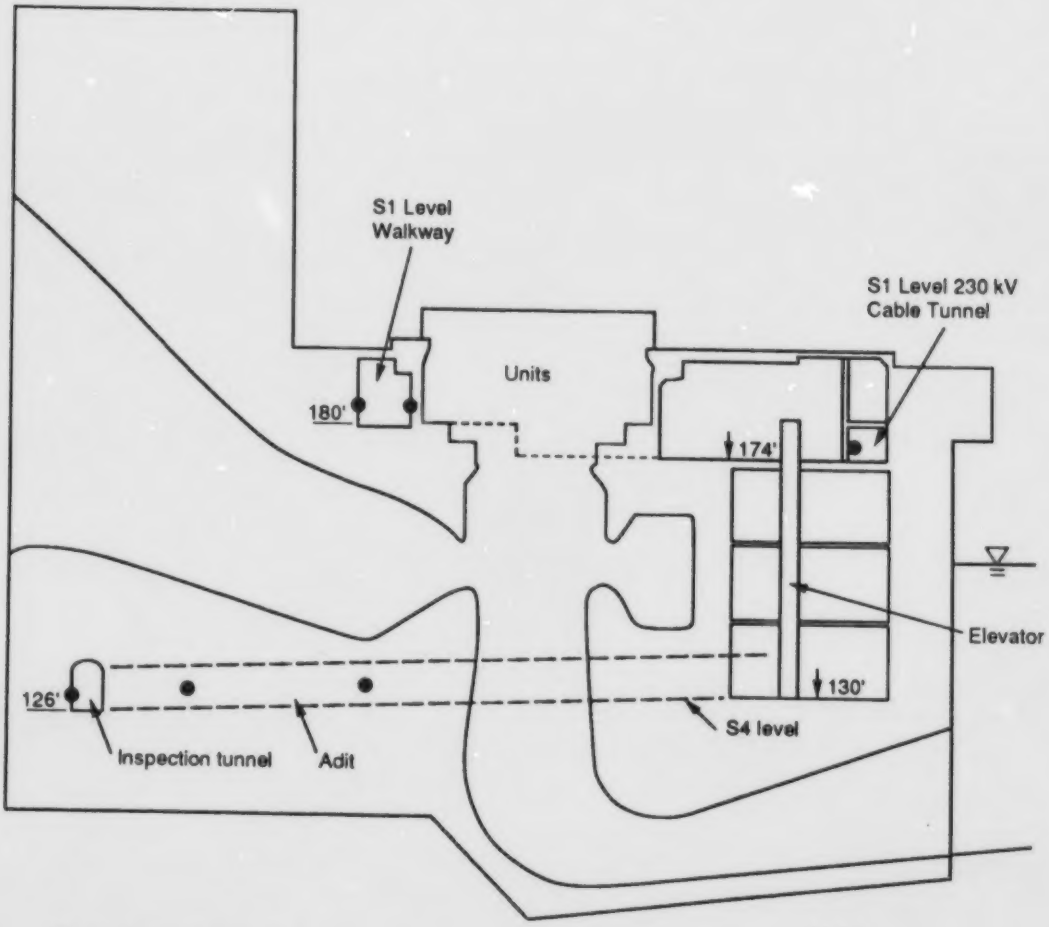


FIGURE 3(a)

SECTION OF R.H. SAUNDERS G.S. SHOWING CRACKMETER LOCATIONS

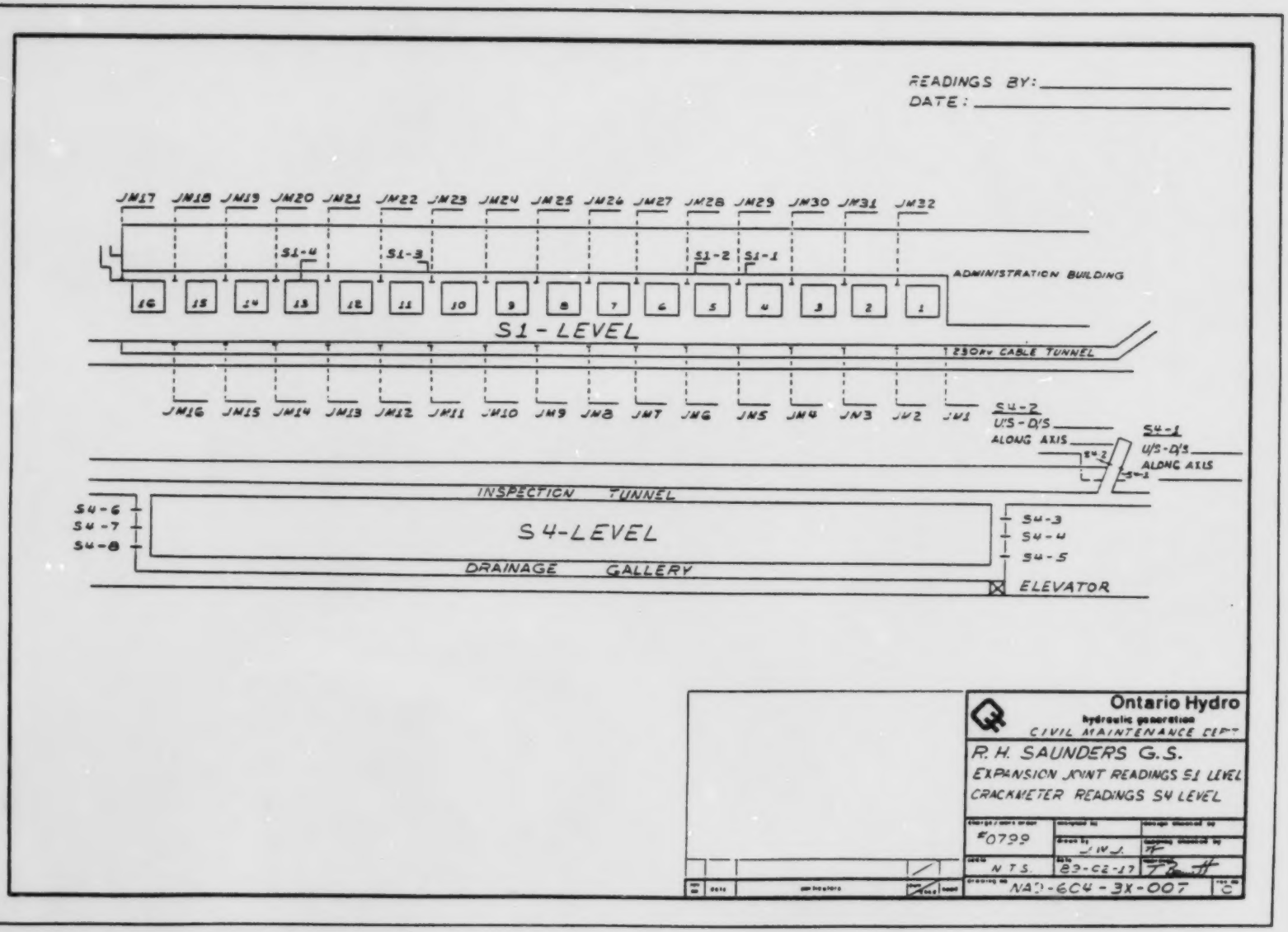


FIGURE 3(b)

PLAN OF CRACKMETER LOCATIONS

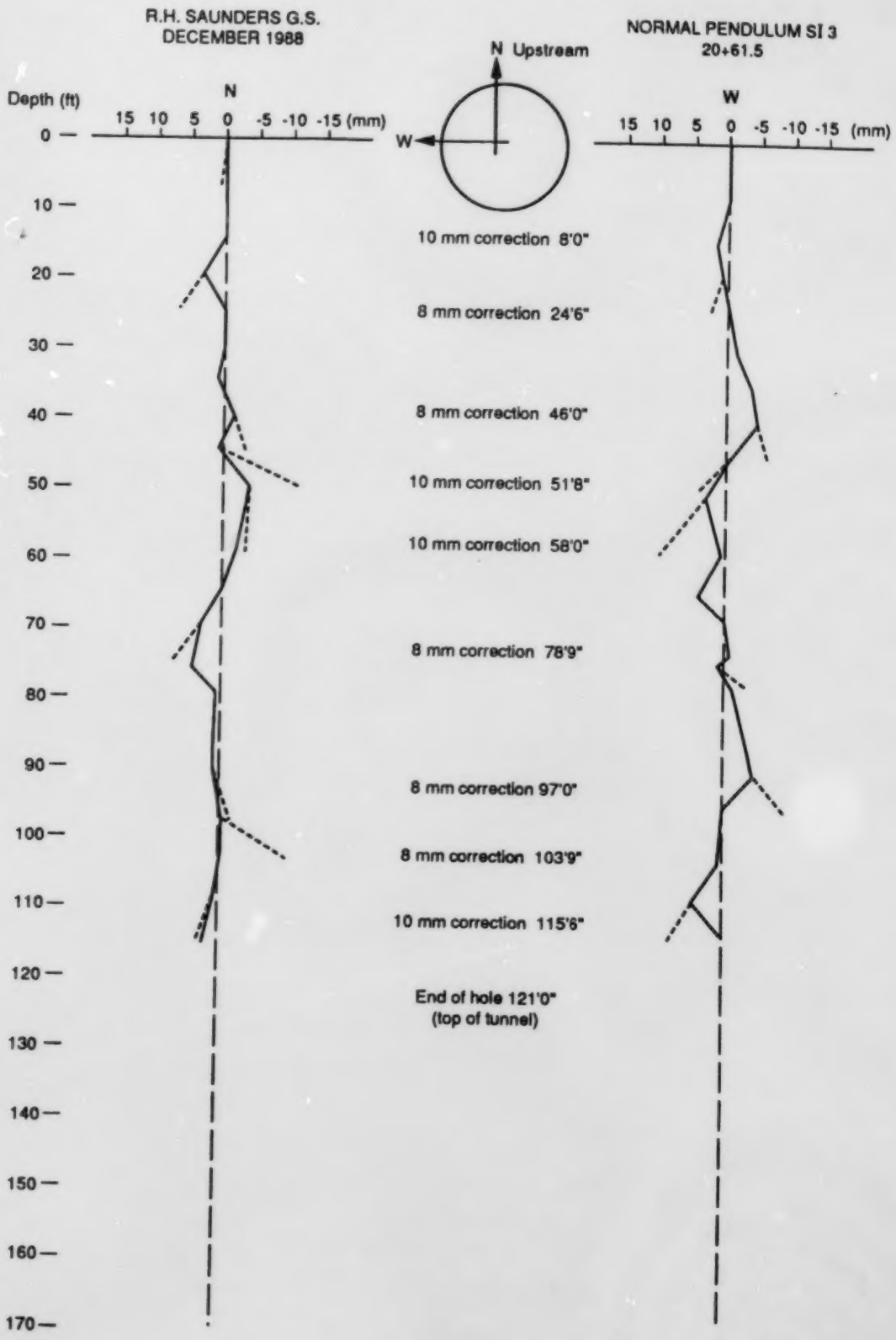


FIGURE 4

R.H. SAUNDERS G.S.
NORMAL PENDULUM AT 20+61.5 ALIGNMENT DURING DRILLING

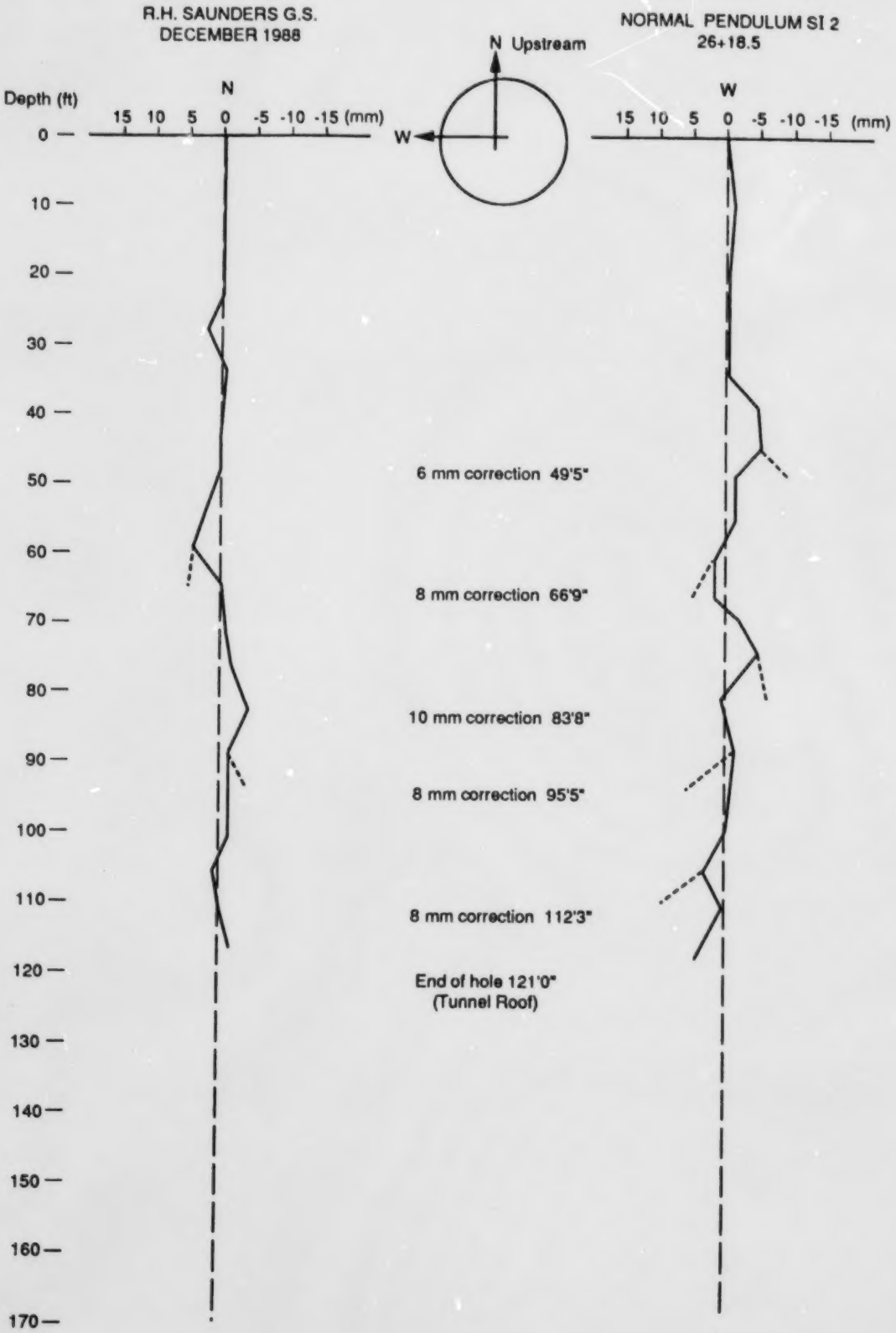
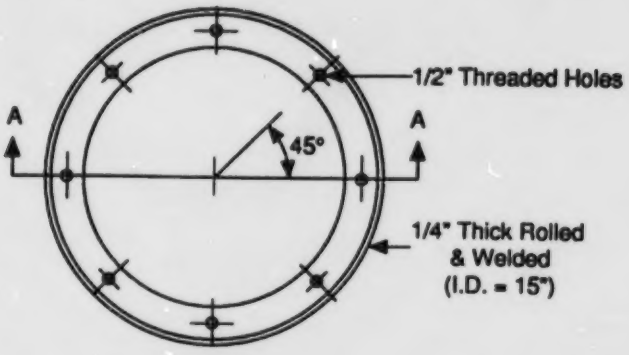
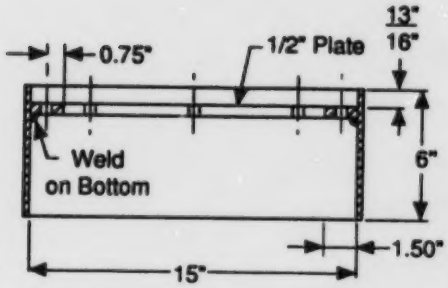


FIGURE 5

R.H. SAUNDERS G.S.
NORMAL PENDULUM AT 26+18.5 ALIGNMENT DURING DRILLING

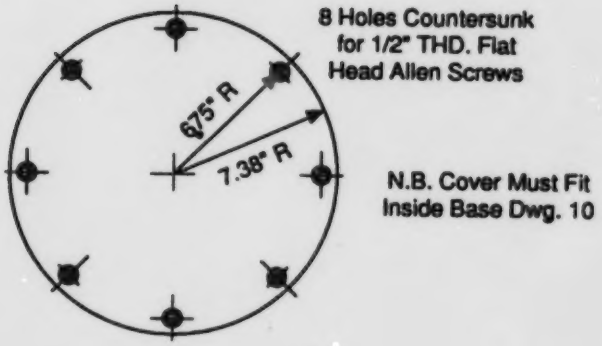


PLAN

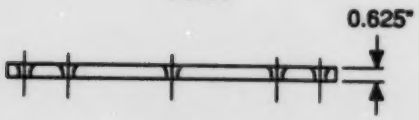


SECTION A-A

Protective Cover Base



PLAN



ELEVATION

Protective Lid

FIGURE 6

NORMAL PENDULUM SUSPENSION AND COVER PLATE DETAILS FOR R.H. SAUNDERS G.S.

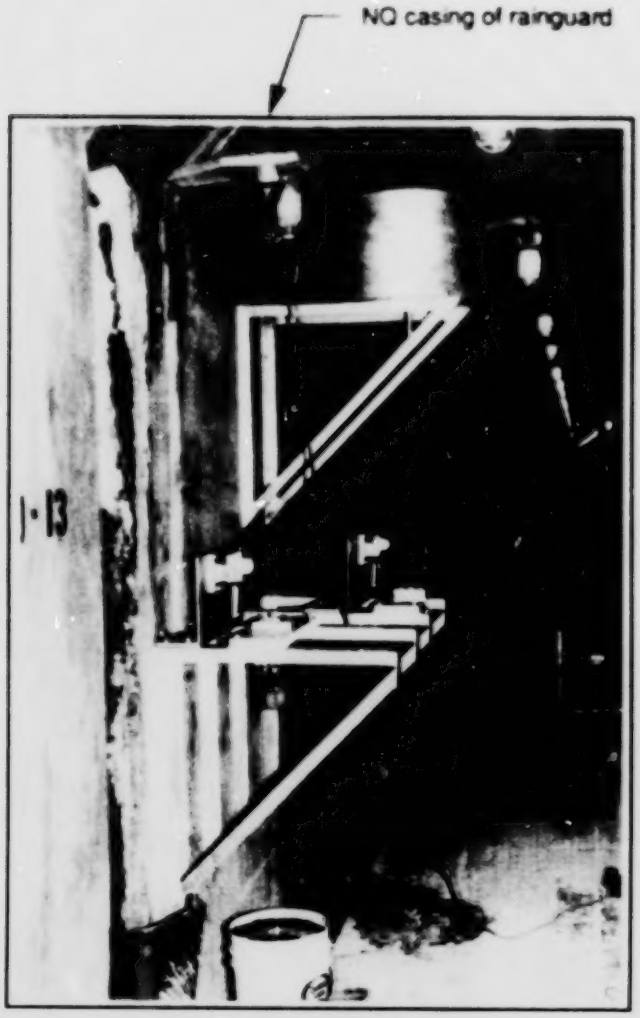


FIGURE 7

PENDULUMS AT R.H. SAUNDERS G.S.
FOREGROUND - NORMAL PENDULUM AT 26 + 18.5
BACKGROUND - INVERSE PENDULUM AT 26 + 15

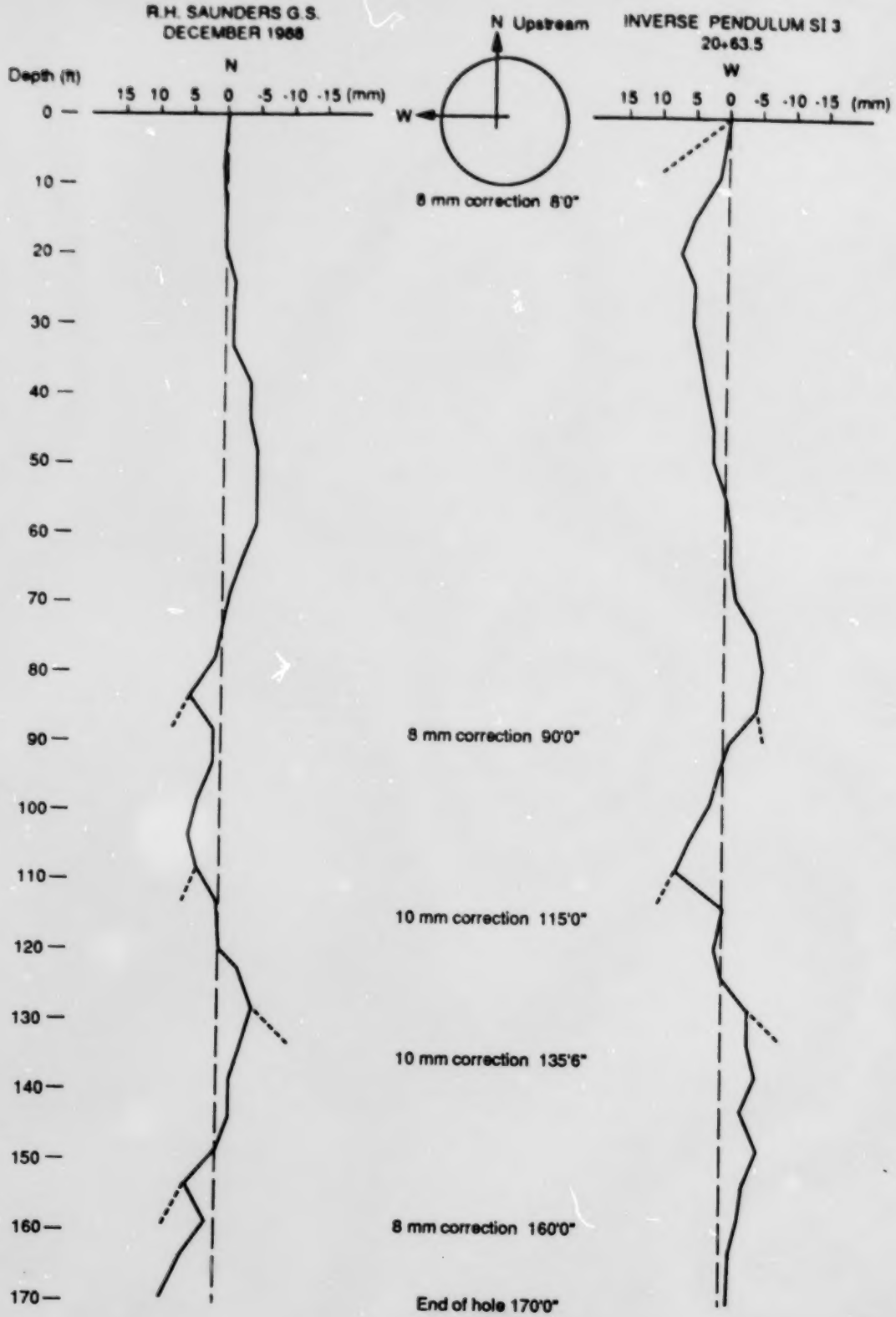


FIGURE 8

R.H. SAUNDERS G.S.
INVERSE PENDULUM AT 20+63.5 ALIGNMENT DURING DRILLING

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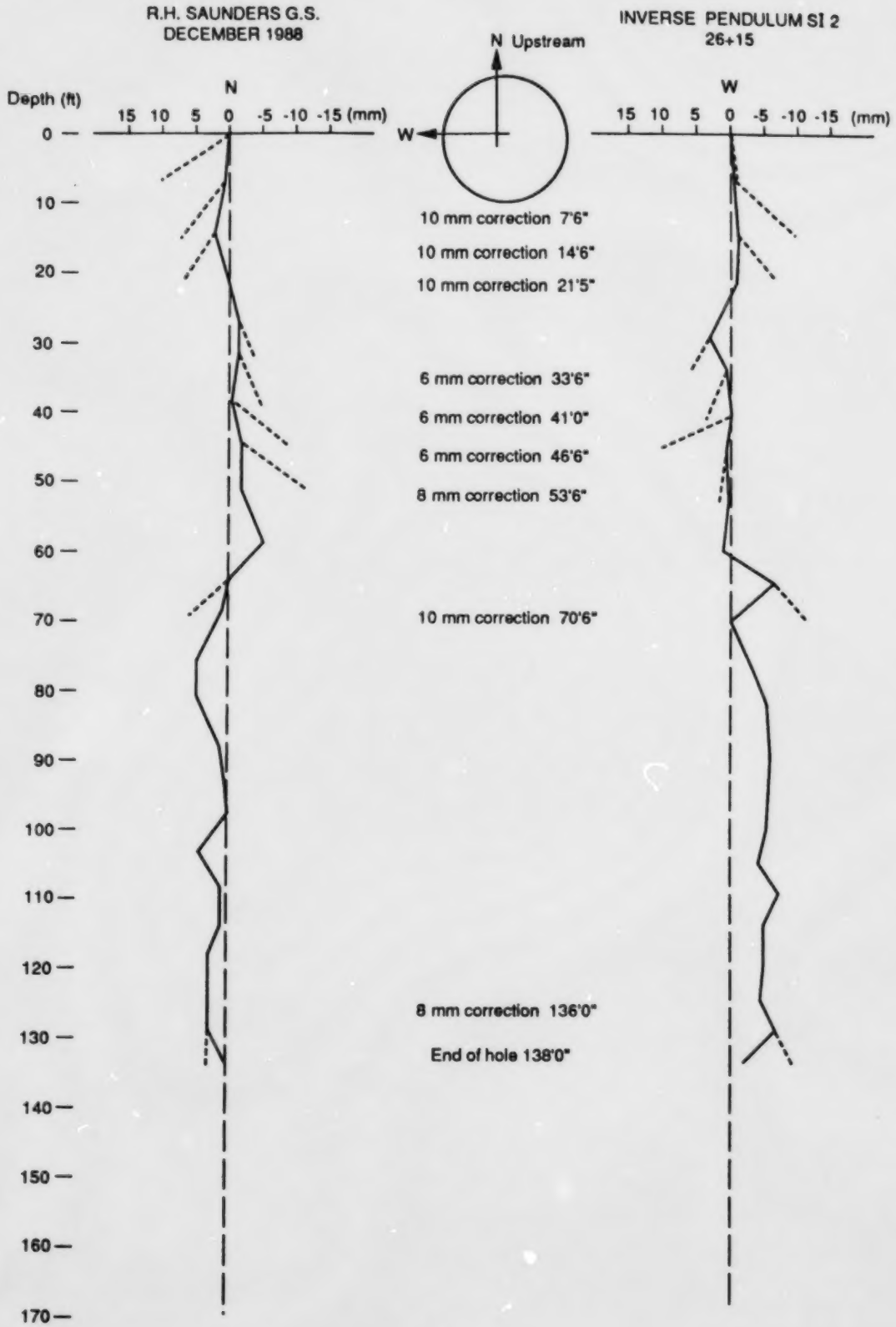
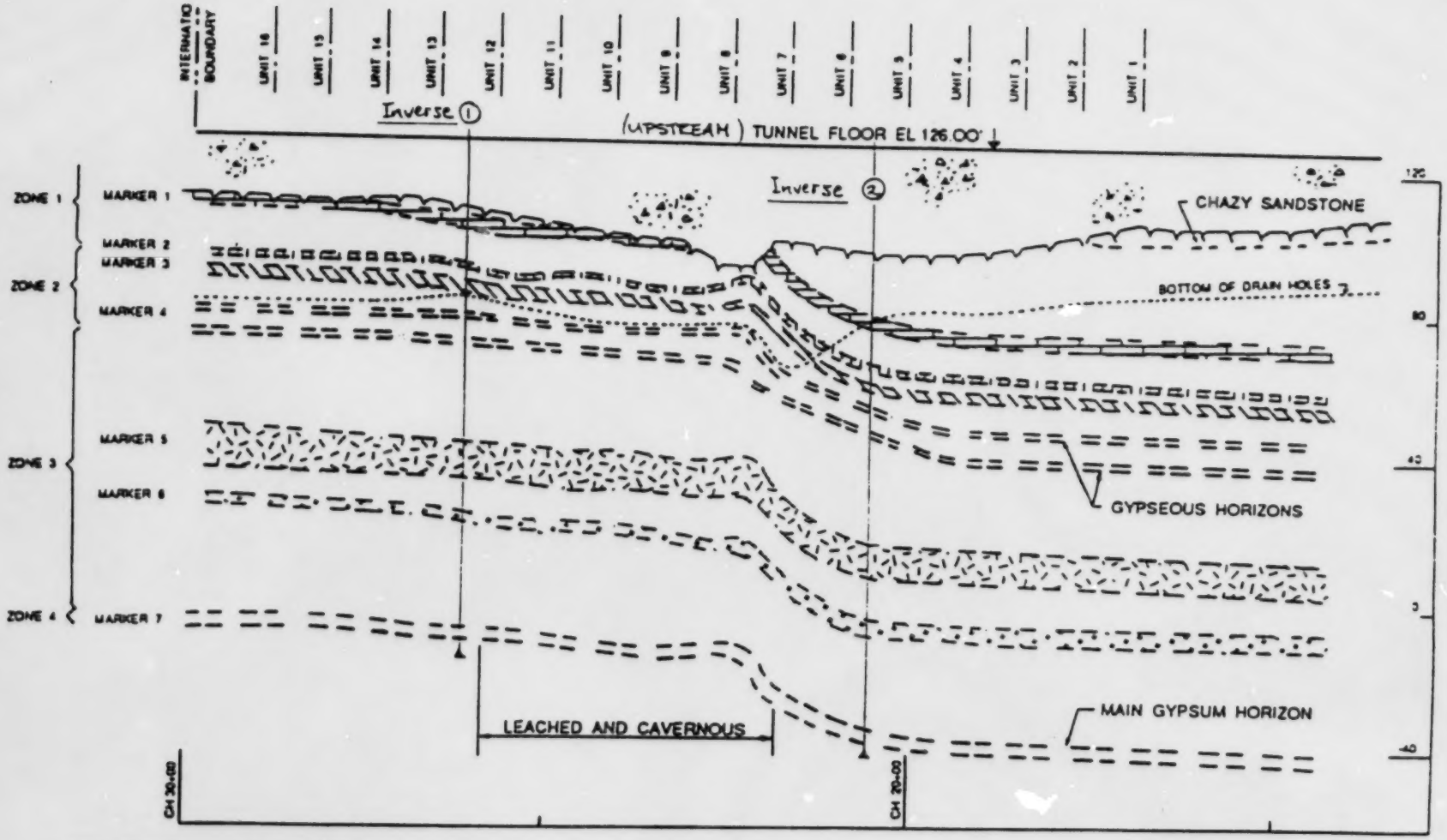


FIGURE 9

R.H. SAUNDERS G.S.
INVERSE PENDULUM AT 26+15 ALIGNMENT DURING DRILLING



NOTE:
ELEVATIONS ARE IN FEET
AND REFERRED TO USLS (1935)

FIGURE TAKEN FROM
REPORT No. GHED - DR - 8615

FIGURE 10

R.H. SAUNDERS G.S.
GENERALIZED GEOLOGICAL SECTION SHOWING PROPOSED PENDULUM LOCATIONS

01-134
185247 RD

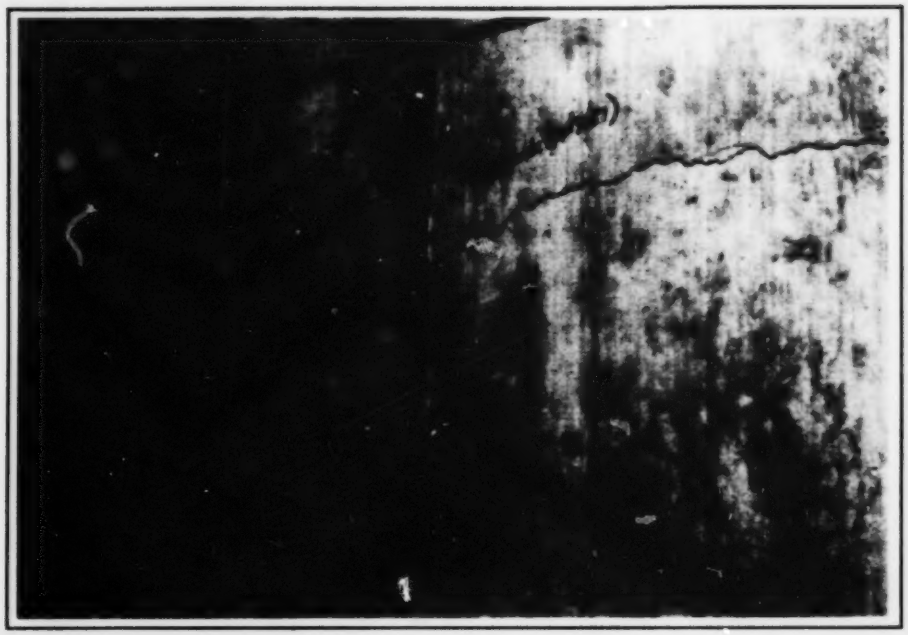


FIGURE 11

TYPICAL CRACK GAUGE AT R.H. SAUNDERS G.S.

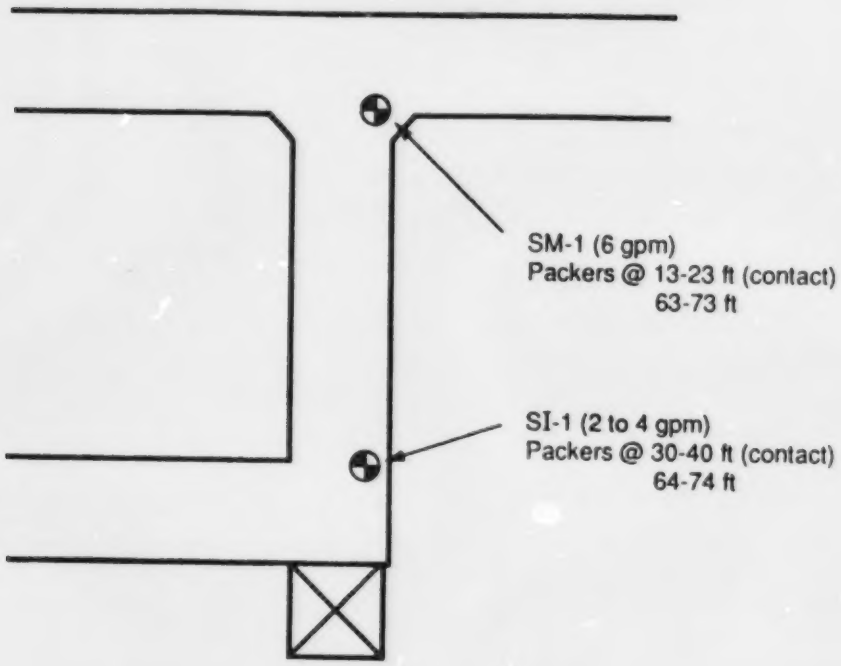
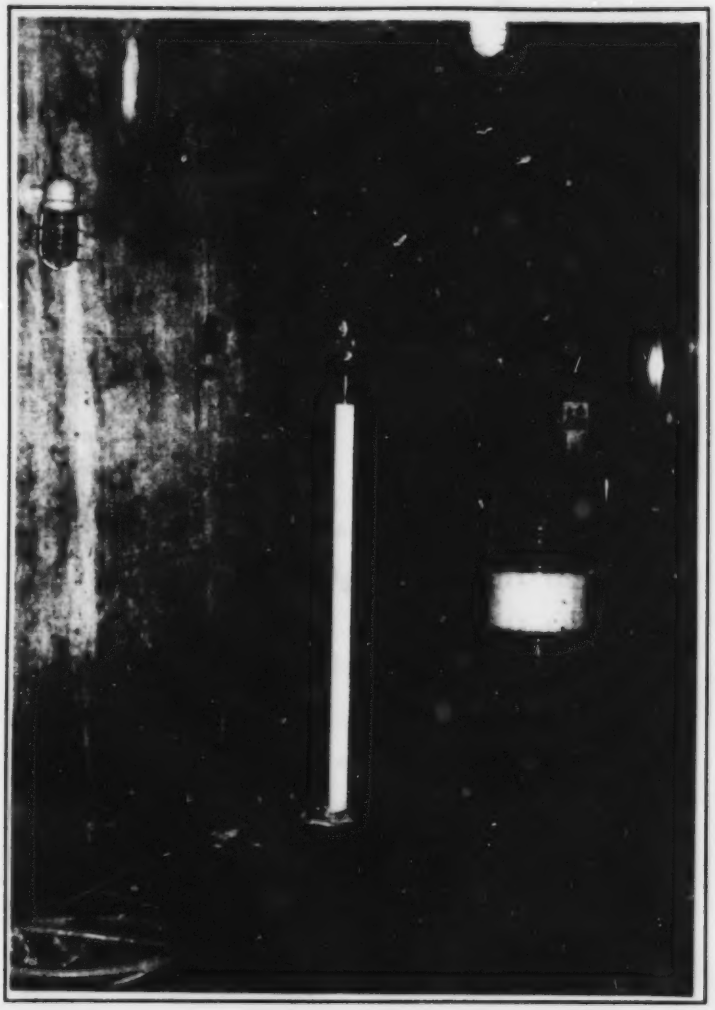
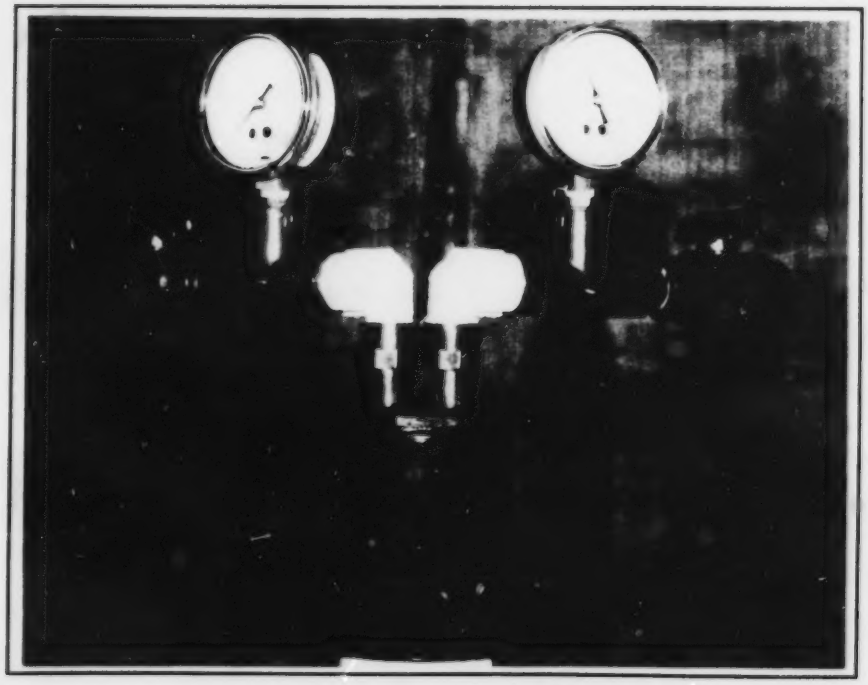


FIGURE 12

MULTILEVEL PIEZOMETER LOCATIONS AT R.H. SAUNDERS G.S.



(a) Installation in S4 level adit near elevator



(b) Closeup of pressure gauges and inert piping components for geochemical sampling

FIGURE 13

MULTILEVEL PIEZOMETER

91-134
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FIGURE 14

PENDULUM READING USING MICROMETER

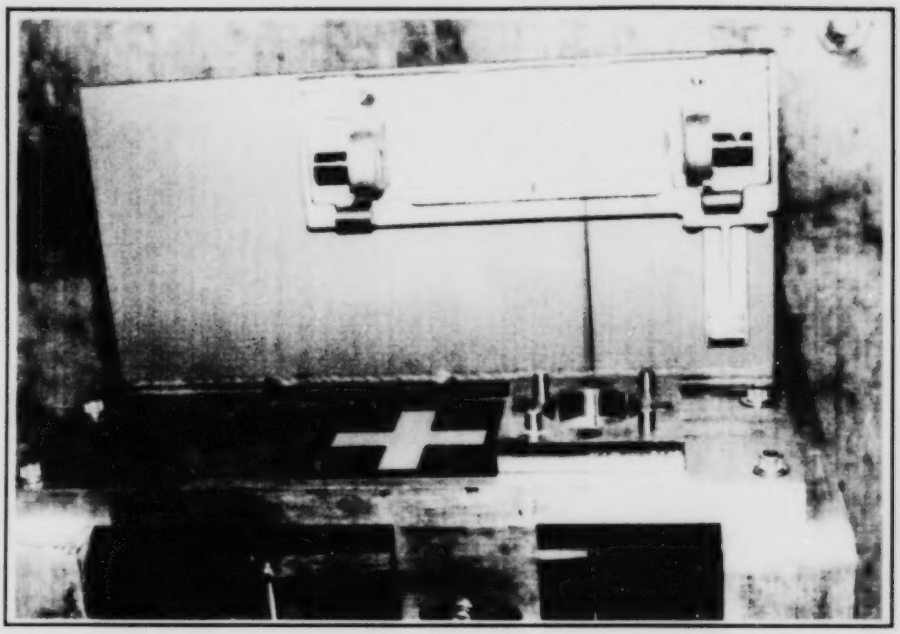

FIGURE 15

PENDULUM TABLE SHOWING MICROMETER REFERENCE POSTS,
MICROLEVEL DECAL AND (BEHIND WIRE) MOUNTING BRACKET FOR COORDISCOPE

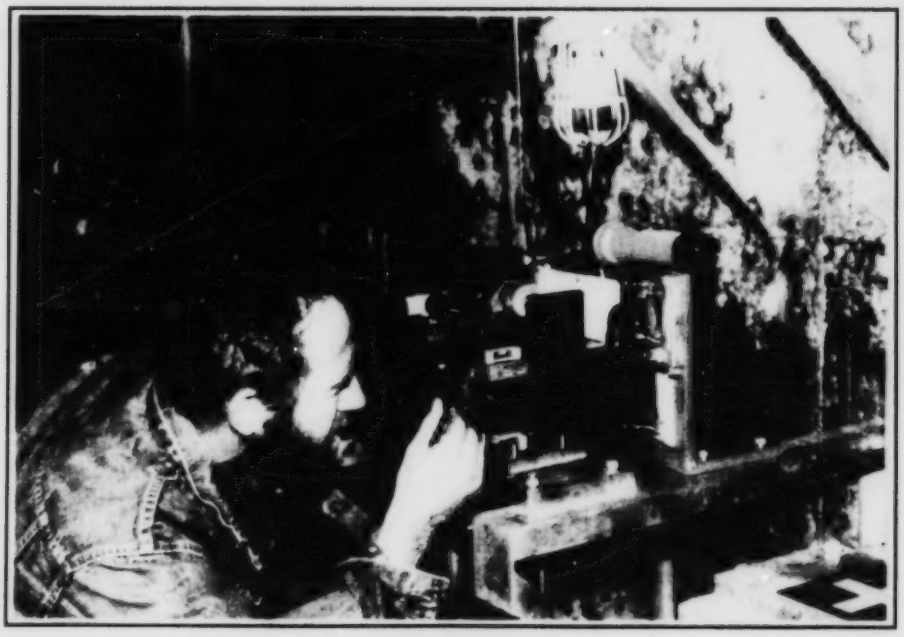

FIGURE 16

COORDISCOPE READING PARALLEL TO THE MAIN DAM AXIS
AT R.H. SAUNDERS G.S.

91-134

185233 RD-AF41

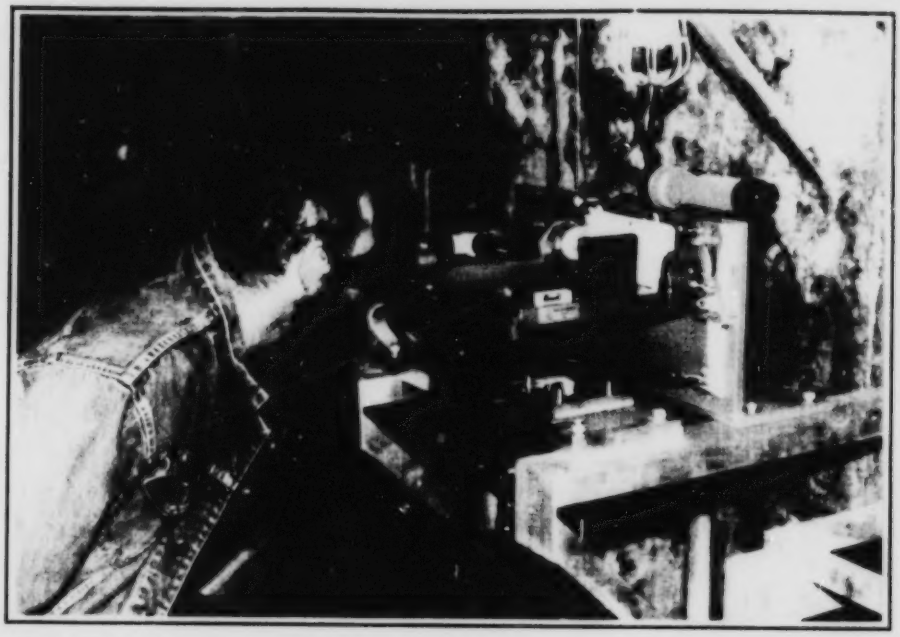

FIGURE 17

COORDISCOPE READING PERPENDICULAR TO THE
MAIN DAM AXIS AT R.H. SAUNDERS G.S.

FIGURE 18

COORDISCOPE REFERENCE STATION

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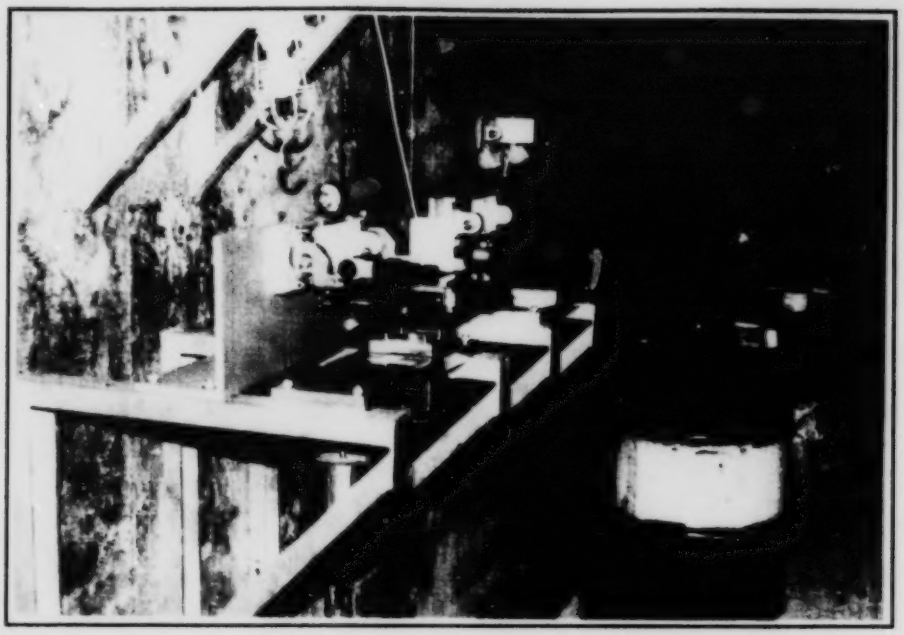

FIGURE 19

PENDULUM AT 20+60, NOTE COORDISCOPE REFERENCE STATION IN BACKGROUND

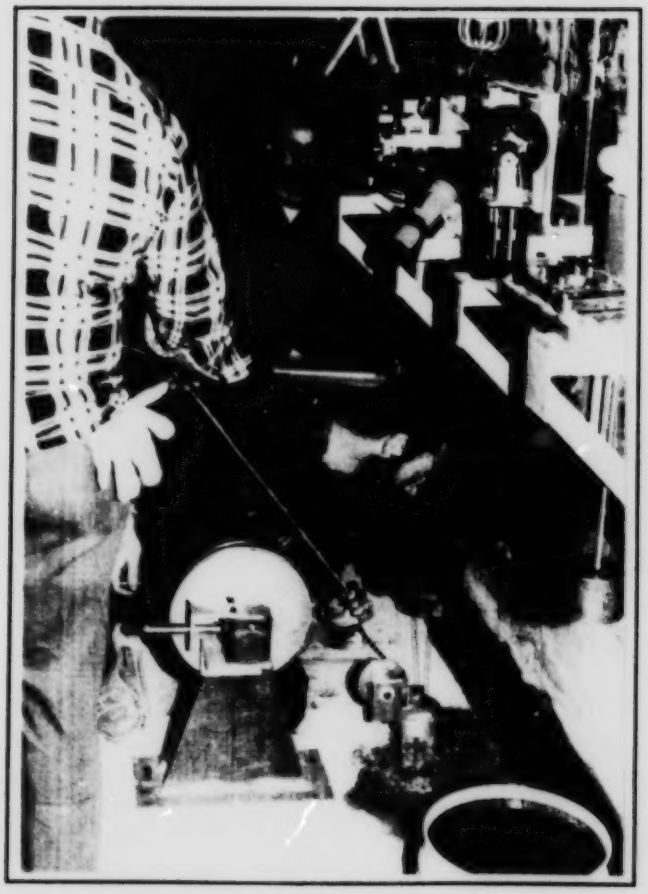

FIGURE 20

AUTOCENTERING READINGS IN PROGRESS AT R.H. SAUNDERS G.S.

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185235 RD-AF41

APPENDIX A

Grouting Records for R.H. Saunders GS Inverse Pendulum Holes

Inverse Pendulum at Chainage 20+63.5

- rock/concrete interface at 29.6 ft
- wet zone at 62 ft
- 1st grouting with hole at 80 ft (inflow 20 gpm at 6 psi)*
- 2nd grouting with hole at 170 ft*

*grouting details in following pages (date, grout pressure, grout take)

Inverse Pendulum at Chainage 26+15

- rock/concrete interface at 17.2 ft
- artesian flow at 38 ft
- 1st grouting with hole at 53 ft (inflow 10 gpm at 5 psi)*
- 2nd grouting at 120 ft (inflow ? gpm at 9 psi)*
- 3rd grouting at 138 ft (inflow 30 gpm at 7 psi)*

*grouting details on following pages (date, grout pressure, grout take)

7431 F2
rev. 7-79

Area Profile KK 10+25

geotechnical department

grouting report - foundation pressure grouting

project	type of grouting	date	grout report no.
R H SAUNDERS	STAGE	OCT. 18 TO NOV. 3/88	
location: S4 INSPECTION TUNNEL	ontario hydro inspector: L. MACKEY & E TREMBLAY		sheet no. 1 of 2

hole number	insert depth	pumping time start	pumping time finish	pressure in p.s.i. start	pressure in p.s.i. finish	cu. ft. placed (wet)	bags cement	w/c	cu. ft. sand	remarks
20+63.5		DATUM IS TOP OF CONCRETE S4 TUNNEL FLOOR								ELEV DATUM = 126.0
		DATUM TO BEDROCK				29.6				" B/R = 96.4
		DATUM TO BOTTOM OF HOLE 177.5								" BOTTOM = -51.5
		ARTESIAN FLOW FROM 55.0 TO 80.0' WAS 20 G.P.M AT 6 P.S.I.								

connections for grouting	vent holes	cu. ft. grout placed (wet)	bags cement placed	cu. ft. sand placed	
water pressure testing (hours)					

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rev. 7-70

grouting report - foundation pressure grouting

project	type of grouting	date	grout report no.
PRESSURE GROUT	LEAKAGE		
location	ontario hydro inspector		sheet no. 2 of 4

hole number	insert depth	pumping time start	pumping time finish	pressure in p.s.i. start	pressure in p.s.i. finish	cu. ft. placed (wet)	bags cement	w/c	cu. ft. sand	remarks
2043.5										
OCT. 18.	48	4:25	5:46	7	37	21.38	6	4.0 / 1.5	—	R/G. @ 5:46
OCT. 25	77	5:45	6:50	12	60	24.05	7.5	4.0 / 1.5	—	R/G @ 6:50
NOV 2	115	5:00	6:45	12	75	24.97	8.0	4.0 / 1.5	—	R/G @ 6:40.
	GROUTED IN PENDULUM CASING									
						3.13.	3	1.0	—	
NOV-2.										
										R

connections for grouting	vent holes	cu. ft. grout placed (wet)	t placed	cu. ft. sand placed	
water pressure testing (hourly)					

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geotechnical department

grouting report - foundation pressure grouting

project	type of grouting	date	grout report no.
R H SAUNDERS G.S.	STAGE	OCT. 15 TO 24/88	
location: S4 INSPECTION TUNNEL	ontario hydro inspector: R. HERNTIER, L. MACKEY, E. TREMBLEY		sheet no. 1 of 3

hole number	insert depth	pumping time start	pumping time finish	pressure in p.s.i. start	pressure in p.s.i. finish	cu. ft. placed (wet)	bags cement	w/c	cu. ft. sand	remarks
26+15		ARTESIAN FLOW FROM 38 TO 48' ±					= 10	G.P.M AT 5 P.S.I.		
	DATUM IS	TOP OF CONCRETE S4 TUNNEL FLOOR.								ELEV OF DATUM = 126.0
	DATUM TO	BEDROCK				17.2				" " B/R = 108.8
	DATUM TO	BOTTOM OF HOLE				138.5				" " BOTTOM = -12.5
OCT. 15	18	12 59	1:50	9	15	10.77	3	4.1/2.5	N.I	R/C @ 1.50 PM @ 15 P.S.I
		[illegible]								
SETTINGS AT		15, 18,		49						
		+ SECONDARY AT.		49						

connections for grouting	vent holes	cu. ft. grout placed (wet)	bags cement placed	cu. ft. sand placed
1	0	10.77	3	0

water pressure testing (hours)

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rev. 7-70

grouting report - foundation pressure grouting

project: R H. SAUNDERS	type of grouting: STAGE	date: OCT. 24/88	grout report no.
location: S4 INSPECTION TUNNEL	ontario hydro inspector: L. MACKEY & E TREMBLEY		sheet no. 2 of 3

hole number	insert depth	pumping time start	pumping time finish	pressure in p.s.i. start	pressure in p.s.i. finish	cu. ft. placed (wet)	bags cement	w/c	cu. ft sand	remarks
26+15		ARTESIAN PRESSURE = 9 P.S.I.				(48/20)				
Oct 24	49	7.01	8:16	40	45	[redacted]	9	4.0/	—	R/f 0.22 c.f.m. @ 45 P.S.I.
⇒						26.82		1.5		R/G.

packer set for grouting	vent holes	cu. ft. grout placed (wet)	bags cement placed	cu. ft. sand placed	

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4165925322

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rev. 7-70

grouting report - foundation pressure grouting

project	type of grouting	date	grout report no.
R H SAUNDERS	STAGE	OCT. 25/88	
location	**ontario hydro inspector**		**sheet no.**
S4 INSPECTION TUNNEL	L MACKEY & E TREMBLEY		3 of 3

hole number	insert depth	pumping time start	pumping time finish	pressure in p.s.i. start	pressure in p.s.i. finish	cu. ft. placed (wet)	bags cement	w/c	cu. ft sand	remarks
26+15		ARTESIAN PRESSURE		FROM		49 TO 138	= 30 GPM AT 7 P.S.I.			
Oct 25	49	1.52	2.50	7	27	24.97	8	4.0 / 1.5	0	2.41 TO 2.46 MECH DELAY R/G @ 2.50 @ 27 P.S.I.
Oct. 25	15	3.40	4.40	15	15	4.15	1	4.0	0	R/G @ 4.40 @ 15 P.S.I

connections for grouting	vent holes	cu. ft. grout placed (wet)	bags cement placed	cu. ft. sand placed	
1	0	29.12	9	0	

SENT BY:ONTARIO HYDRO-GHED ; 2-16-89 ; 13:07 ; 4165925322→ 416 231 9679;# 3

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APPENDIX B

Borehole Logs for Inverse Pendulum Drillholes at R.H. Saunders GS

project R.H. SAUNDERS GS
location INSPECTION TUNNEL CH 28+15
datum USLS (1935)
dip 90°
bearing —
hole type ROTARY DRILL
hole size NQ
drilled 05-21 OCT 88
drawn 20 FEB 89 RM
observer E. Trumbley
compiled J.D. Grasa
checked JDG, MH
approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / ROD %	water level and caving	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	128.00				W.A.	DATUM - TUNNEL FLOOR										
2						CONCRETE										
4																
6																
8																
10																
12																
14																
16																
	108.80					Concrete/Bedrock contact (bonded)										
18	17.20					OXFORD FORMATION DOLOSTONE: grey, fine grained, hard, massive bedded, lightly fractured										
20																
	105.00															
22	21.00					OXFORD FORMATION LIMESTONE: white, fine grained, hard, massive bedded, lightly fractured (Marker #1)										
24	101.40															
	24.80					OXFORD FORMATION DOLOSTONE: grey, fine grained, hard, massive bedded, lightly fractured										
26																
28																
30																
32																
34																
36	90.10					OXFORD FORMATION SHALY DOLOSTONE: dark grey, fine grained, weathered, friable shaly layers (Marker #2)										
	89.50															
	38.50					OXFORD FORMATION LIMESTONE: dark brown, fine grained, hard, massive bedded, lightly fractured										
38	87.05															
	40.95															
40	88.00					For Description See Sheet 2 of 4										
	40.00					CONTINUED ON SHEET 2 OF 4										

file name: sound_k/sd2.rhs

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geotechnical data sheet

hole no. SI-2
fig.
sheet 1 of 4

project R.H. SAUNDERS GS
location INSPECTION TUNNEL CH 26+15
datum USLS (1935)
dip 90°
bearing ---
hole type ROTARY DRILL
hole size NQ
drilled 05-21 OCT 88
drawn 20 FEB 89 RM
observer E. Trumbley
compiled J.D. Grass
checked JDG, MH
approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - m	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	88.00				W.R.	CONTINUED FROM SHEET 2 OF 4										
42	85.00 / 41.00					OXFORD FORMATION LIMESTONE (CORAL TYPE): dark brown, fine grained, vuggy, weathered, minor grout present (Marker #3)											
44						OXFORD FORMATION DOLOSTONE: grey, fine grained, massive bedded, lightly fractured											
46																
48						48.8'- 49.0': vuggy, limestone bed											
50																
52																
54	72.30 / 53.70					53.5'-53.7': vuggy, limestone layer										
56						OXFORD FORMATION SHALY DOLOSTONE: grey, fine grained, thinly bedded											
58	68.50 / 57.50					OXFORD FORMATION DOLOSTONE: grey, fine grained, massive bedded, lightly fractured											
60																
62																
64																
66																
68																
70																
72																
74																
76						75.9'-76.3': limestone bed sm\ grout											
78																
80	48.00 / 80.00					CONTINUED ON SHEET 3 OF 4										

file name: saund_lk\si2\s2.rhs

Ontario Hydro
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Geotechnical & Hydraulic Engineering

geotechnical data sheet

hole no. SI-2
fig.
sheet 2 of 4

project R.H. SAUNDERS GS
location INSPECTION TUNNEL CH 26+15
datum USLS (1935)
dip 90°
bearing —
hole type ROTARY DRILL
hole size NQ
drilled 05-21 OCT 88
drawn 20 FEB 89 RM
observer E. Trumbley
compiled J.D. Grass
checked JDG, MH
approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - m	elev / depth	sample no.	sample type	'N' value per ft / ROD %	water level and caving	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psf type	shear strength psf results	special tests type	special tests results
	48.00				W.A.	CONTINUED FROM SHEET 2 OF 4										
	45.00					For Description See Sheet 2 of 4										
82	81.00					OXFORD FORMATION DOLOSTONE: grey, fine grained, microfractured, healed with calcite, thin shaly beds throughout (Marker #5)										
84																
86																
88																
90																
92																
	33.20															
94	92.80					OXFORD FORMATION DOLOSTONE: grey, fine grained, massive bedded, lightly fractured										
96																
98																
100	26.00															
	100.00					OXFORD FORMATION DOLOSTONE: grey, fine grained, arenaceous (sandy), massive bedded (Marker #8)										
102																
104	21.70															
	104.30					OXFORD FORMATION DOLOSTONE: grey, fine grained, massive bedded, lightly fractured										
106						104.3'-105.3': shaly bed										
108						108.5': grout (1/8")										
110																
112						111.38': grout (1/4")										
114						113.28': grout (1/4") 113.92': grout (1/4")										
116						116.4'-118.9': shaly section										
118						118.9': grout (1/8") 119.82': grout with shale (1/2" - 1 1/2")										
120	8.00 120.00					CONTINUED ON SHEET 4 OF 4										

file name: saund_lb/el2e3.rhe

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geotechnical data sheet

hole no. SI-2
fig.
sheet 3 of 4

project	R.H. SAUNDERS GS		hole type	ROTARY DRILL	observer E. Trumbley
location	INSPECTION TUNNEL CH 26+15		hole size	NQ	compiled J.D. Grass
		dip 90°	drilled	05-21 OCT 88	checked JDG, MH
datum	USLS (1935)	bearing —	drawn	20 FEB 89 RM	approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/ rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture % content	shear strength psi type	shear strength psi results	special tests type	special tests results
	6.00				W.R.	CONTINUED FROM SHEET 3 OF 4										
122						OXFORD FORMATION DOLOSTONE: grey, fine grained, massive bedded, lightly fractured										
124																
126						125.65'-126.1': breccia zone with grout										
128																
130						130.2'-131.0': joint (15°)										
132						132.3': joint (25°)										
134	-7.10 133.10					OXFORD FORMATION GYPSUM: black and white (zebra texture), massive bedded (Marker #7)										
136	-10.00 136.00					OXFORD FORMATION DOLOSTONE: grey, fine grained, massive bedded, lightly fractured										
138	-12.50 135.50					END OF BOREHOLE CR = 100%										
140						NOTES: 1. Geological contacts are approximate 2. Grouting was done as borehole progressed 3. Inverted pendulum installed by Civil Research 1988										

file name: saund_lb/el2a4.rhs

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geotechnical data sheet

hole no. SI-2 | fig.

sheet 4 of 4

project R.H. SAUNDERS GS
location INSPECTION TUNNEL CH 20+63.5
datum USLS (1935)
dip 90°
bearing —
hole type ROTARY DRILL
hole size NQ
drilled 4 OCT-2 NOV 88
drawn 20 FEB 89 RM
observer E. Trumbley
compiled J.D. Grass
checked JDG, MH
approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/ rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psf type	shear strength psf results	special tests type	special tests results
	128.00				W.R.	DATUM = TUNNEL FLOOR										
2						CONCRETE										
4																
6																
8																
10																
12																
14																
16																
18																
20																
22																
24																
26																
28																
30	98.50 / 29.50					Concrete/Bedrock contact (unbonded)										
32						OXFORD FORMATION DOLOSTONE: grey, fine grained, massive bedded, fairly fractured										
34						31.3'-31.55': thin shaly layers										
36						35.2', 37.4', 39.3': thin shaly layers										
38																
40	88.00 / 40.00					CONTINUED ON SHEET 2 OF 5										

file name: esund_it\sl3.rhs

Ontario Hydro
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geotechnical data sheet

hole no. SI-3
fig.
sheet 1 of 5

project	R.H. SAUNDERS GS			hole type	ROTARY DRILL	observer	E. Trumbley
location	INSPECTION TUNNEL CH 20+63.5			hole size	NQ	compiled	J.D. Grass
		dip	90°	drilled	4 OCT-2 NOV 88	checked	JDG, MH
datum	USLS (1935)	bearing	—	drawn	20 FEB 89 RM	approved	B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/ rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	86.00				W.R.	CONTINUED FROM SHEET 2 OF 5										
42						For Description See Sheet 1 of 5 41.0': grout filled joint (25°) 41.3'-41.6': shaly bed										
44	81.60 44.40					OXFORD FORMATION LIMESTONE: white, fine grained, massive bedded, lightly fractured (Marker #1)										
46																
48																
50	78.00 50.00					OXFORD FORMATION DOLOSTONE: grey, fine grained, massive bedded, lightly fractured										
52																
54																
56																
58																
60	66.00 60.00					OXFORD FORMATION SHALY DOLOSTONE: dark grey, fine grained, weathered, friable, shaly layers (Marker #2)										
	64.90 61.10															
62	63.40 62.60					OXFORD FORMATION DOLOSTONE: grey, fine grained, massive bedded, lightly fractured										
64						OXFORD FORMATION LIMESTONE (CORAL TYPE): dark brown, fine grained, vuggy, weathered (Marker #3)										
66	59.30 58.70															
68						OXFORD FORMATION SHALY DOLOSTONE: grey, fine grained, thinly bedded, some vuggy limestone layers and grout-filled bedding planes										
70																
72																
74																
76	51.00 75.00					OXFORD FORMATION DOLOSTONE: grey, fine grained, thin to massive bedded, minor shaly sections, some grout sections in limestone layers										
78																
80	48.00 80.00					CONTINUED ON SHEET 3 OF 5										

file name: ssund_it/sl3s2.rhs

Ontario Hydro
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Geotechnical & Hydraulic Engineering

geotechnical data sheet

hole no. SI-3 | fig.

sheet 2 of 5

project R.H. SAUNDERS GS
location INSPECTION TUNNEL CH 20+63.5
datum USLS (1935)
dip 90°
bearing —
hole type ROTARY DRILL
hole size NQ
drilled 4 OCT-2 NOV 88
drawn 20 FEB 89 RM
observer E. Trumbley
compiled J.D. Grass
checked JDG, MH
approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/ rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	46.00				W.R.	CONTINUED FROM SHEET 2 OF 5										
	45.30					For Description See Sheet 2 of 5										
82	81.40					OXFORD FORMATION SHALY DOLOSTONE: grey, fine grained, with gypsum infilling bedding planes (Marker #4)										
84																
86						OXFORD FORMATION DOLOSTONE: grey, fine grained, thin to massive bedded, lightly fractured with some shaly sections, minor gypsum										
88																
90																
92																
94																
96																
98																
100																
102						102.0': gypsum layer (1")											
104																
106																
108	19.00 107.00					OXFORD FORMATION DOLOSTONE: grey, fine grained, thin to massive bedded, lightly fractured with some shaly sections, minor grout											
110																
112																
114																
116																
118	7.40 114.60															
120	6.00 120.00					For Description See Sheet 4 of 5										
						CONTINUED ON SHEET 4 OF 5										

file name: saund_il/sl3s3.rls

Ontario Hydro
Design & Construction Branch
Geotechnical & Hydraulic Engineering

geotechnical data sheet

hole no. SI-3
fig.
sheet 3 of 5

project R.H. SAUNDERS GS
location INSPECTION TUNNEL CH 20+83.5
datum USLS (1935)
dip 90°
bearing —
hole type ROTARY DRILL
hole size NQ
drilled 4 OCT-2 NOV 88
drawn 20 FEB 89 RM
observer E. Trumbley
compiled J.D. Grasa
checked JDG, MH
approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - m	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/ rock cm/s: water press. test	special tests: type	special tests: results	natural density lb/ft³	moisture content %	shear strength psf: type	shear strength psf: results	special tests: type	special tests: results
	6.00				W.R.	CONTINUED FROM SHEET 3 OF 5										
122						OXFORD FORMATION DOLOSTONE: grey, fine grained, massive bedded										
124																
	1.00 125.00															
126						OXFORD FORMATION DOLOSTONE: grey, fine grained, arenaceous (sandy), massive bedded, (Marker #8)											
128																
130	-4.00 130.00															
						OXFORD FORMATION DOLOSTONE: grey, fine grained, thin to massive bedded, several thin shale beds throughout											
132																
134																
136																
138																
140																
142																
144																
146																
148																
150																
152						152.0'-152.8': zebra textured gypsum with white fibrous gypsum											
154																
156																
158																
160	-34.00 160.00					CONTINUED ON SHEET 5 OF 5										

file name: saund_b/sl3s4.rhs

Ontario Hydro
Design & Construction Branch
Geotechnical & Hydraulic Engineering

geotechnical data sheet

hole no. SI-3
fig.
sheet 4 of 5

project R.H. SAUNDERS GS
location INSPECTION TUNNEL CH 20+83.5
datum USLS (1935)
dip 90°
bearing —
hole type ROTARY DRILL
hole size NQ
drilled 4 OCT-2 NOV 88
drawn 20 FEB 89 RM
observer E. Trumbley
compiled J.D. Grase
checked JDG, MH
approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	% soil/ rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	-34.00				W.R.	CONTINUED FROM SHEET 4 OF 5										
	160.20					For Description See Sheet 4 of 5										
182						OXFORD FORMATION GYPSUM: zebra texture, massive bedded, some white fibrous gypsum (Marker #7)											
	-97.30 183.30															
184						OXFORD FORMATION DOLOSTONE: grey, fine grained, massive bedded, lightly fractured, minor gypsum layers present											
186																
188																
170																
172																
174																
176																
	-51.50 177.50															
178						END OF BOREHOLE CR = 100%											
180						NOTES: 1. Geological contacts are approximate 2. Grouting carried out as hole progressed 3. Inverted pendulum installed by Civil Research 1988											

file name: saund_kfe3e5.xls

Ontario Hydro
Design & Construction Branch
Geotechnical & Hydraulic Engineering

geotechnical data sheet

hole no. 91-3
fig.
sheet 5 of 5

91-134

APPENDIX C

Initial Autocentering Readings on R.H. Saunders GS
Normal Pendulums Installed in 1988

·Reading Date: November 23/88

R.H. SAUNDERS GS

North is U/S
20+61.5

Normal Pendulum 11/23/88 - Computed by AM/BJ/MH

	North*	South*	East*	West*
118	1.470	1.600	1.315	1.758
115	1.508	1.565	1.328	1.748
110	1.553	1.517	1.259	1.817
105	1.531	1.541	1.277	1.803
100	1.448	1.564	1.418	1.649
95	1.520	1.549	1.491	1.580
90	1.625	1.438	1.550	1.517
85	1.663	1.407	1.615	1.457
80	1.672	1.407	1.635	1.441
75	1.749	1.320	1.578	1.491
70	1.863	1.209	1.404	1.656
65	1.801	1.267	1.284	1.791
60	1.667	1.404	1.276	1.800
55	1.532	1.534	1.297	1.780
50	1.370	1.688	1.278	1.792
45	1.318	1.755	1.354	1.720
40	1.410	1.658	1.420	1.650
35	1.479	1.588	1.462	1.606
30	1.504	1.558	1.479	1.597
25	1.604	1.445	1.469	1.609
20	1.782	1.283	1.428	1.641
15	1.800	1.269	1.359	1.718
10	1.855	1.235	1.237	1.830
5	1.819	1.261	1.284	1.786
SURFACE	1.777	1.298	1.325	1.737

Readings After Autocentering

	North	South	East	West
	1.561	1.511	1.509	1.555
at pipe	1-8/32	1	1-12/32	29/32

*all negative numbers

R.H. SAUNDERS GS

North is U/S
26+18.5

Normal Pendulum

11/12/88 - Computed by AM/BJ/MH

	North*	South*	East*	West*
118	1.321	1.746	1.558	1.514
115	1.243	1.821	1.520	1.547
110	1.263	1.809	1.547	1.531
105	1.367	1.703	1.548	1.524
100	1.334	1.736	1.515	1.553
95	1.269	1.799	1.533	1.538
90	1.245	1.821	1.584	1.477
85	1.221	1.851	1.732	1.340
80	1.273	1.791	1.765	1.308
75	1.284	1.790	1.684	1.384
70	1.343	1.726	1.628	1.445
65	1.423	1.651	1.625	1.448
60	1.437	1.635	1.606	1.469
55	1.491	1.578	1.546	1.527
50	1.521	1.547	1.563	1.505
45	1.487	1.593	1.709	1.369
40	1.463	1.618	1.743	1.343
35	1.508	1.577	1.729	1.361
30	1.582	1.514	1.726	1.362
25	1.531	1.545	1.583	1.489
20	1.470	1.609	1.567	1.508
15	1.443	1.634	1.661	1.437
10	1.518	1.575	1.680	1.401
5	1.565	1.520	1.641	1.441
SURFACE	1.592	1.489	1.605	1.469

Readings After Autocentering

	North	South	East	West
	1.577	1.511	1.526	1.564
at pipe	1-11/32	28/32	1-2/32	1-6/32

*all negative numbers

APPENDIX D

Summary of Initial Inverse and Normal Pendulum Table Readings
at R.H. Saunders GS

·Reading Dates: November 23/1988
December 7,8,9, 1988
January 24, 25, 1989
April 4,5,7, 1989

TABLE D1

R.H. Saunders GS - Pendulum Readings
During Installation (Nov/Dec 1988) and Inspection (April 1989)
Using Digital Depth Micrometer (Manual Reading)

Pendulum Type	Pendulum Location	Reading Date	Readings			
			N	S	E	W
Nor	20+61.5	Nov 23/88	1.561	1.511	1.509	1.555
		Dec 7/88	1.570	1.501	1.525	1.546
		Jan 25/89	1.614	1.460	1.536	1.540
Nor	20+61.5	Apr 4/89	1.610	1.463	1.531	1.544
Nor	26+18.5	Nov 23/88	1.577	1.511	1.526	1.564
		Dec 8/88	1.611	1.464	1.522	1.545
		Jan 24/89	1.668	1.405	1.519	1.555
		Apr 5/89	1.650	1.423	1.526	1.547
Inv	20+63.5	Dec 7/88	1.492	1.576	1.428	1.646
		Jan 25/89	1.453	1.619	1.419	1.660
		Apr 7/89	1.433	1.644	1.406	1.671
Inv	26+15	Dec 8/88	1.605	1.467	1.470	1.607
		Jan 24/89	1.566	1.507	1.485	1.589
		Apr 7/89	1.543	1.536	1.486	1.587

compiled August 21/89, CBC

TABLE D2

R.H. Saunders GS - Pendulum Readings
During Installation (Nov/Dec 1988) & Inspection (April 1989)
Using Optical Coordiscope

Pendulum Type	Pendulum Location	Reading Date	Readings*	
			S	W
Nor	20+61.5	Dec 9/88	5.023	1.108
		Jan 25/89	5.017	1.154
		Apr 5/89	5.028	1.149
Nor	26+18.5	Dec 9/88	3.712	1.190
		Jan 24/89	3.713	1.243
		Apr 5/89	3.714	1.228
Inv	20+63.5	Dec 9/88	5.628	1.157
		Jan 25/89	5.610	1.139
		Apr 5/89	5.613	1.146
Inv	26+15	Dec 9/88	5.422	1.116
		Jan 24/89	5.389	1.106
		Apr 5/89	5.389	1.113

*NOTE: Coordiscope W = Micrometer N direction
and Coordiscope S = Micrometer W direction

compiled Aug 21/89, CBC

TABLE D3

R.H. Saunders GS - Invar Wire Extensometer
Readings at Pendulum Locations
During Installation (Nov/Dec 1988) & Inspection (April 1989)
Using Digital Depth Micrometer (Manual Reading)

Pendulum Type	Pendulum Location	Reading Date	Readings (vertical)
Nor	20+61.5	Nov 23/88 Dec 7/88 Jan 25/89 Apr 4/89	N/A 2.450 2.446 2.659 (ball bearing missing)
Nor	26+18.5	Nov 23/88 Dec 8/88 Jan 24/89 Apr 5/89	N/A 2.294 2.368 2.357
Inv	20+63.5	Dec 7/88 Jan 25/89 Apr 7/89	2.535 2.463 2.454
Inv	26+15	Dec 8/88 Jan 24/89 Apr 7/89	2.221 2.210 2.192

compiled Oct 12/89, CBC

APPENDIX E

Autocenering Readings on Inverse Pendulums
Installed at R.H. Saunders GS in 1988

·Reading Dates: Dec 7,8,9/88
Apr 4,5/89

R.H. Saunders GS
Datum Readings - Coordiscope
(inches)

Dec 9/88

Calibration Block 20 + 55

South 3.6915
West 0.331

Inverse Pendulum (SI3) 20+63.5

South 5.628
West 1.157

Inverse Pendulum (SI2) 26+15

South 3.7125
West 1.190

NOTE: South = telescope on south side of wire, reading is comparable to micrometer West reading

West = telescope on west side of wire, reading is comparable to micrometer North reading

mechanics convention used - North is upstream

R.H. Saunders GS
Autocentering Readings by Coordiscope
Inverse Pendulum 20+63.5

Dec 7/88

Depth (ft)	South (inches)	West (inches)
0	5.701	0.920
5	5.927	0.852
10	6.007	0.848
15	6.020	0.784
20	5.992	0.729
25	5.945	0.698
30	5.924	0.700
35	5.909	0.710
40	5.938	0.709
45	5.913	0.670
50	5.845	0.677
55	5.801	0.714
60	5.760	0.714
65	5.721	0.748
70	5.674	0.803
75	5.596	0.853
80	5.596	0.894
85	5.650	0.936
90	5.698	0.987
95	5.810	1.064
100	5.942	1.083
105	5.982	1.045
110	5.955	0.976
115	5.875	0.886
120	5.801	0.832
125	5.668	0.742
130	5.554	0.720
135	5.559	0.702
140	5.589	0.727
145	5.612	0.745
150	5.620	0.762
155	5.458	0.767
160	5.458	0.805

R.H. Saunders GS
Autocentering Readings by Coordiscope
Inverse Pendulum 26+15

Dec 8/88

Depth (ft)	South (inches)	West (inches)
0	5.493	1.035
5	5.578	0.976
10	5.600	1.015
15	5.610	0.999
20	5.671	0.911
25	5.747	0.786
30	5.781	0.670
35	5.780	0.605
40	5.775	0.558
45	5.730	0.565
50	5.563	0.637
55	5.616	0.754
60	5.517	0.839
65	5.482	0.901
70	5.471	0.961
75	5.475	0.979
80	5.490	0.985
85	5.515	1.001
90	5.524	0.983
95	5.515	0.978
100	5.489	1.002
105	5.453	1.009
110	5.438	0.981
115	5.427	1.006
120	5.668	1.015
125	5.554	0.742
130	5.559	0.720
135	5.589	0.702
140	5.612	0.727
145	5.620	0.745
150	5.458	0.762
155	5.458	0.767
160		0.805

R.H. Saunders GS
Autocentering Readings by Coordiscope
Inverse Pendulum 26+15

Dec 9/88

Depth (ft)	South (inches)	West (inches)
0	5.489	1.029
5	5.574	0.982
10	5.560	1.018
15	5.605	1.000
20	5.660	0.913
25	5.742	0.788
30	5.777	0.676
35	5.777	0.607
40	5.774	0.563
45	5.729	0.565
50	5.669	0.636
55	5.616	0.751
60	5.516	0.837
65	5.486	0.896
70	5.473	0.957
75	5.475	0.979
80	5.490	0.996
85	5.511	0.994
90	5.516	0.985
95	5.501	0.998
100	5.510	1.006
105	5.505	1.004
110	5.485	1.014
115	5.492	1.063
120	5.481	

R.H. Saunders GS
Autocentering Readings by Coordiscope
Inverse Pendulum 20 + 63.5

Depth (ft)	April 4/89		April 5/89	
	North (inch)	West (inch)	North (inch)	West (inch)
reference	1.120	5.609	1.126	5.607
0	0.885	5.753	0.881	5.757
5	0.824	5.932	0.826	5.939
10	0.823	6.018	0.827	6.022
15	0.761	6.038	0.767	6.042
20	0.704	6.009	0.711	6.012
25	0.670	5.965	0.678	5.964
30	0.669	5.943	0.678	5.945
35	0.675	5.920	0.683	5.922
40	0.671	5.948	0.683	5.948
45	0.612	5.928	0.651	5.923
50	0.066	5.861	0.659	5.853
55	0.660	5.823	0.696	5.818
60	0.661	5.784	0.696	5.777
65	0.692	5.746	0.727	5.744
70	0.742	5.697	0.781	5.697
75	0.789	5.618	0.821	5.614
80	0.831	5.614	0.862	5.659
86	0.871	5.666	0.902	5.717
90	0.919	5.698	0.942	5.809
95	0.989	5.821	1.007	5.879
100	1.019	5.926	1.023	5.877
105	1.002	5.938	0.994	5.825
110	0.933	5.889	0.917	5.754
115	0.844	5.811	0.824	5.705
120	0.737	5.752	0.730	5.601
125	0.676	5.648	0.668	5.505
130	0.647	5.562	0.630	5.552
135	0.648	5.575	0.666	5.572
140	0.684	5.585	0.702	5.591
145	0.715	5.606	0.730	5.593
150	0.761	5.594	0.777	5.590
155	0.793	5.585	0.815	5.565
160	0.831	5.553	0.845	
Calibration Block (Apr 5/89			0.3305	3.6935
(change from Dec 9/88)			-0.0005	+0.002

R.H. Saunders GS
Autocentering Readings by Coordiscope
Inverse Pendulum 26+15

Depth (ft)	April 5/89	
	North (inch)	West (inch)
reference	1.113	5.389
0	1.022	5.496
5	0.970	5.577
10	1.006	5.597
15	0.991	5.603
20	0.901	5.662
25	0.777	5.735
30	0.666	5.770
35	0.609	5.766
40	0.524	5.772
45	0.535	5.732
50	0.609	5.666
55	0.720	5.617
60	0.792	5.524
65	0.838	5.496
70	0.888	5.482
75	0.913	5.484
80	0.914	5.497
85	0.934	5.519
90	0.932	5.520
95	0.926	5.500
100	0.944	5.495
105	0.957	5.467
110	0.961	5.441
115	0.961	5.434
120	0.965	5.429

Inverted Pendulum
Datum Readings

Page 1 of 10

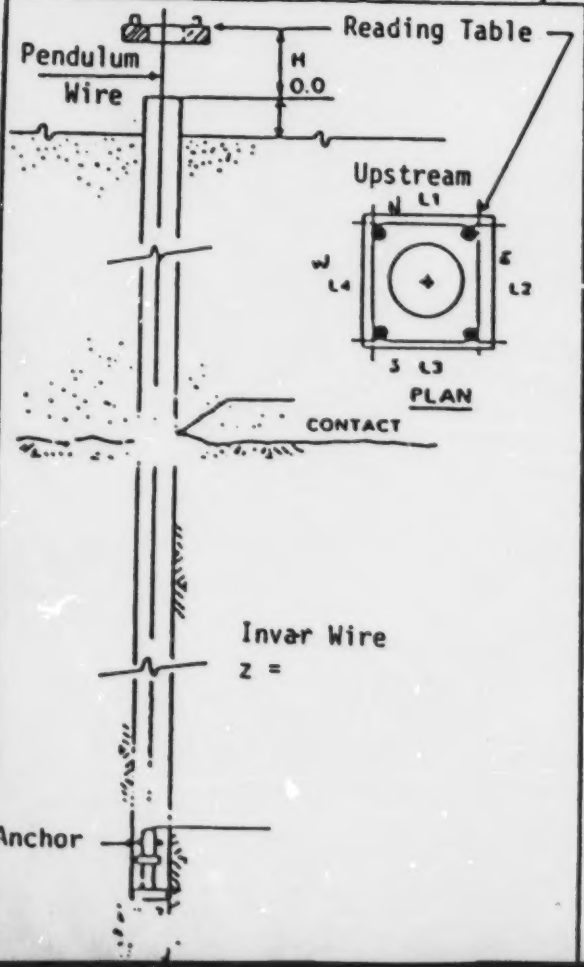
DATE: Dec 7/88

TEMP.:

Observer AC
Marker Brian
Chainage 20+65.5
Elevation

PROJECT: R.H. Saunders G.S.

Depth (ft)	Axis	Rdg No	Reading Inches	Position	Actual Position	Original Position	Displacement
Reading Table H =	X	L2	1.428	.109	(Px)		
		L4	1.646				
		L2					
		L4					
	Y	L1	1.492	.042	(Py)		
		L3	1.576				
		L1					
		L3					



Position of centre of the reading table relative to the pendulum anchor

$x = \frac{L4 - L2}{2}$ $y = \frac{L3 - L1}{2}$

Auto centering device
Position of the wire, at various depths relative to the pendulum anchor

$x = \frac{L2 - L4}{2} + Px$

$y = \frac{L1 - L3}{2} + Py$

Table Constant x = 3.098 + .047 = 3.145

y = 3.092 + .047 = 3.139

Wire Diameter = .047

DATE: DEC 7/80

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

2 OF 10

L.H. SAUNDERS G.S. PLOT:

A. A BRIAN
20+685
INVERSE SE3

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
SURFACE	X	L2 ↓	1.273	-.151			
		L4 ↓	1.797				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.209	-.285			
		L3 ↓	1.863				
		L1 ↑					
		L3 ↑					
5	X	L2 ↓	1.086	-.342			
		L4 ↓	1.967				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.151	-.341			
		L3 ↓	1.917				
		L1 ↑					
		L3 ↑					
10	X	L2 ↓	1.011	-.417			
		L4 ↓	2.063				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.156	-.338			
		L3 ↓	1.915				
		L1 ↑					
		L3 ↑					
15	X	L2 ↓	0.995	-.432			
		L4 ↓	2.077				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.081	-.440			
		L3 ↓	1.985				
		L1 ↑					

DATE: Dec 7/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

3 OF 10

Ard Beam
20+63.5
INVERSE SET 3

R.H. SANDERS G.S. PLOT:

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
20	X	L2	1.029	-.400			
		L4	2.047				
		L2					
		L4					
	Y	L1	1.029	-.463			
		L3	2.038				
		L1					
		L3					
25	X	L2	1.075	-.354			
		L4	2.000				
		L2					
		L4					
	Y	L1	0.993	-.498			
		L3	2.072				
		L1					
		L3					
30	X	L2	1.088	-.340			
		L4	1.986				
		L2					
		L4					
	Y	L1	0.996	-.498			
		L3	2.075				
		L1					
		L3					
35	X	L2	1.090	-.344			
		L4	1.996				
		L2					
		L4					
	Y	L1	0.983	-.510			
		L3	2.087				
		L1					

DATE: Dec 7/60

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

4 OF 10

R. H. SANDERS G.S. PLOT:

Ar 4 Brain
20+68.5
INVERSE SI3

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
40	X	L2	1.079	-.351			
		L4	1.998				
		L2					
		L4					
	Y	L1	1.008	-.487			
		L3	2.065				
		L1					
		L3					
45	X	L2	1.108	-.321			
		L4	~~1.968~~				
		L2					
		L4					
	Y	L1	0.968	-.526			
		L3	2.104				
		L1					
		L3					
50	X	L2	1.175	-.257			
		L4	1.~~205~~ 206				
		L2					
		L4					
	Y	L1	0.983	-.515			
		L3	2.096				
		L1					
		L3					
55	X	L2	1.233	-.207			
		L4	1.865				
		L2					
		L4					
	Y	L1	1.035	-.471			
		L3	2.061				
		L1					

DATE: Dec 7/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

5 OF 10

L.H. SAUNDERS G-S. PLOT:

ABUTMENT
20+63.5
INVERSE SET 3

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
60	X	L2 ↓	1.249	.187 E			
		L4 ↓	1.840				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.020	-.486			
		L3 ↓	2.076				
		L1 ↑					
		L3 ↑					
65	X	L2 ↓	1.311	-.128			
		L4 ↓	1.784				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.063	-.439			
		L3 ↓	2.024				
		L1 ↑					
		L3 ↑					
70	X	L2 ↓	1.358	-.080			
		L4 ↓	1.736				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.121	-.382			
		L3 ↓	1.968				
		L1 ↑					
		L3 ↑					
75	X	L2 ↓	1.443	.007			
		L4 ↓	1.647				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.157	-.342			
		L3 ↓	1.925				
		L1 ↑					

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91-134

DATE: _____

TEMP.: DEC 7/88

INVERSE PENDULUM
AUTO-CENTERING DEVICE

6 OF 10

R.H. SAUNDERS G.S. PLOT: _____

ALBANY
20 FEB. 5
INVERSE [illegible]

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
80	X	L2 ↓	1.443	-.005			
		L4 ↓	1.671				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.197	-.305			
		L3 ↓	1.891				
		L1 ↑					
		L3 ↑					
85	X	L2 ↓	1.379	-.059			
		L4 ↓	1.714				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.239	-.266			
		L3 ↓	1.854				
		L1 ↑					
		L3 ↑					
90	X	L2 ↓	1.309	-.113			
		L4 ↓	1.752				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.276	-.217			
		L3 ↓	1.794				
		L1 ↑					
		L3 ↑					
95	X	L2 ↓	1.191	-.239			
		L4 ↓	1.886				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.354	-.140			
		L3 ↓	1.718				
		L1 ↑					

Pa: _____

DATE: _____

TEMP.: _____

INVERSE PENDULUM
AUTO-CENTERING DEVICE

7 OF 10

20T69.5

PLOT: _____

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
100	X	L2 ↓	1.066	-.365			
		L4 ↓	2.013				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.382	-.113			
		L3 ↓	1.692				
		L1 ↑					
		L3 ↑					
105	X	L2 ↓	1.050	-.378			
		L4 ↓	2.024				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.381	-.114			
		L3 ↓	1.692				
		L1 ↑					
		L3 ↑					
110	X	L2 ↓	1.110	-.316			
		L4 ↓	1.959				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.301	-.191			
		L3 ↓	1.766				
		L1 ↑					
		L3 ↑					
115	X	L2 ↓	1.178	-.248			
		L4 ↓	1.892				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.210	-.283			
		L3 ↓	1.860				
		L1 ↑					

DATE: Oct 7/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

8 OF 10

R. H. SANDERS GS PLOT:

A. Abram
20-68.5
INVERSE SI3

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
120	X	L2	1.270	-.157			
		L4	1.801				
		L2					
		L4					
	Y	L1	1.136	-.355			
		L3	1.929				
		L1					
		L3					
125	X	L2	1.400	-.030			
		L4	1.678				
		L2					
		L4					
	Y	L1	1.032	-.460			
		L3	2.037				
		L1					
		L3					
130	X	L2	1.500	.071E			
		L4	1.577				
		L2					
		L4					
	Y	L1	1.010	-.486			
		L3	2.065				
		L1					
		L3					
135	X	L2	1.493	.061			
		L4	1.589				
		L2					
		L4					
	Y	L1	0.998	-.495			
		L3	2.072				
		L1		66			

DATE: Dec 7/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

9 of 10

R.H. SAUNDERS G-5. PLOT:

A-4 Bend
20+63.5
INVERSE SET

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
140	X	L2	1.462	.033			
		L4	1.615				
		L3					
		L4					
	Y	L1	1.034	-.461			
		L3	2.040				
		L1					
		L3					
145	X	L2	1.464	.034			
		L4	1.614				
		L2					
		L4					
	Y	L1	1.085	-.409			
		L3	1.986				
		L1					
		L3					
150	X	L2	1.466	.037			
		L4	1.611				
		L2					
		L4					
	Y	L1	1.160	-.334			
		L3	1.912				
		L1					
		L3					
155	X	L2	1.492	.061			
		L4	1.586				
		L2					
		L4					
	Y	L1	1.217	-.277			
		L3	1.854				
		L1					

DATE: Dec 7/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

10 OF 10

R. H. Brown
20+63.5
INVERSE SE 3

R-H. SAUNDERS G-S. PLOT:

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
160	X	L2	1.526	-.101			
		L4	1.542				
		L2					
		L4					
	Y	L1	1.408	-.098			
		L3	1.687				
		L1					
		L3					
	X	L2					
		L4					
		L2					
		L4					
	Y	L1					
		L3					
		L1					
		L3					
	X	L2					
		L4					
		L2					
		L4					
	Y	L1					
		L3					
		L1					
		L3					
	X	L2					
		L4					
		L2					
		L4					
	Y	L1					
		L3					
		L1					
		L3					

DATE: Dec 7/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

2 OF 10

2ND SET

L.H. SAMDEX'S G.S. PLOT:

Al 4 Bram
20+69.5
Inverse 553

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
SURFACE	X	L2 ↓	1.281	-.149			
		L4 ↓	1.796				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.205	-.291			
		L3 ↓	1.871				
		L1 ↑					
		L3 ↑					
5	X	L2 ↓	1.091	-.336			
		L4 ↓	1.981				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.149	-.345			
		L3 ↓	1.922				
		L1 ↑					
		L3 ↑					
10	X	L2 ↓	1.010	-.420			
		L4 ↓	2.067				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.152	-.343			
		L3 ↓	1.922				
		L1 ↑					
		L3 ↑					
15	X	L2 ↓	1.001	-.429			
		L4 ↓	2.076				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.086	-.408			
		L3 ↓	1.906				
		L1 ↑					
		L3 ↑					

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91-134

DATE: Dec 7/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

3 of 10

2ND SET

R.H-SAN-DEYES G-S. PLOT:

20+65.5

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
20	X	L2 ↓	1.036	-.396			
		L4 ↓	2.045				
		L3 ↑					
		L4 ↑					
	Y	L1 ↓	1.031	-.463			
		L3 ↓	2.041				
		L1 ↑					
		L3 ↑					
25	X	L2 ↓	1.106	-.340			
		L4 ↓	2.004				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.003	-.496			
		L3 ↓	2.078				
		L1 ↑					
		L3 ↑					
30	X	L2 ↓	1.102	-.333			
		L4 ↓	1.986				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.002	-.498			
		L3 ↓	2.082				
		L1 ↑					
		L3 ↑					
35	X	L2 ↓	1.115	-.325			
		L4 ↓	1.986				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.015	-.483			
		L3 ↓	2.064				
		L1 ↑					
				70			

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DATE: Dec 7/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

4 OF 10

2ND SET

R-H SAN-DERS G.S. PLOT:

Rt of Dam
20+65.5
IN DRG SI3

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
40	X	L2 ↓	1.085	-.349			
		L4 ↓	2.000				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.009	-.493			
		L3 ↓	2.079				
		L1 ↑					
		L3 ↑					
45	X	L2 ↓	1.113	-.317			
		L4 ↓	1.965				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	0.978	-.452	-0.524		
		L3 ↓	1.965				
		L1 ↑	0.119				
		L3 ↑					
50	X	L2 ↓	1.188	-.245			
		L4 ↓	1.896				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	0.987	-.517			
		L3 ↓	2.104				
		L1 ↑					
		L3 ↑					
55	X	L2 ↓	1.222	-.209			
		L4 ↓	1.857				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.018	-.478			
		L3 ↓	2.057				
		L1 ↑		71			91-134

DATE: Dec 7/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

5 OF 10

2ND SET

R.H. SAMPLE S.G.S. PLOT:

Adj Level
20+68.5
INVERSE DF 3

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
60	X	L2 ↓	1.268	-.163			
		L4 ↓	1.812				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.020	-.461			
		L3 ↓	2.065				
		L1 ↑		1.3.7			
		L3 ↑					
65	X	L2 ↓	1.507	-.024	-0.124		
		L4 ↓	1.773				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.057	-.440			
		L3 ↓	2.021				
		L1 ↑					
		L3 ↑					
70	X	L2 ↓	1.348	-.079			
		L4 ↓	1.725				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.118	-.383			
		L3 ↓	1.968				
		L1 ↑					
		L3 ↑					
75	X	L2 ↓	1.435	.004			
		L4 ↓	1.648				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.156	-.344			
		L3 ↓	1.928				
		L1 ↑					
		L3 ↑					

DATE: Dec 7/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

6 OF 10

2ND SET

R.H. SAUNDERS G.S.

PLOT:

Ar & Blast
20 to 95
INVERSE SET 3

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
80	X	L2 ↓	1.432	0.000			
		L4 ↓	1.650				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.194	-.301			
		L3 ↓	1.880				
		L1 ↑					
		L3 ↑					
85	X	L2 ↓	1.374	-.055			
		L4 ↓	1.702				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.238	-.256			
		L3 ↓	1.838				
		L1 ↑					
		L3 ↑					
90	X	L2 ↓	1.322	-.105			
		L4 ↓	1.749				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.274	-.216			
		L3 ↓	1.790				
		L1 ↑					
		L3 ↑					
95	X	L2 ↓	1.175	-.250			
		L4 ↓	1.893				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.371	-.123			
		L3 ↓	1.700				
		L1 ↑		73			91-134

DATE: Dec 7/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

7 OF 10

2ND SET

R.H SAUNDERS G.S. PLOT:

20+65.5
INVERSE SET

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
100	X	↓ L2	1.106	-.320			
		↓ L4	1.964				
		↑ L2					
		↑ L4					
	Y	↓ L1	1.396	-.099			
		↓ L3	1.677				
		↑ L1					
		↑ L3					
105	X	↓ L2	1.120	-.308			
		↓ L4	1.954				
		↑ L2					
		↑ L4					
	Y	↓ L1	1.365	-.127			
		↓ L3	1.702				
		↑ L1					
		↑ L3					
110	X	↓ L2	1.192	-.234			
		↓ L4	1.877				
		↑ L2					
		↑ L4					
	Y	↓ L1	1.279	-.213			
		↓ L3	1.789				
		↑ L1					
		↑ L3					
115	X	↓ L2	1.274	-.150			
		↓ L4	1.791				
		↑ L2					
		↑ L4					
	Y	↓ L1	1.176	-.315			
		↓ L3	1.890				
		↑ L1					

DATE: Dec 7/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

8 OF 10

2ND SET

R. H. SAUNDERS G-S- PLOT:

DR ABRAM
20+69.5
INVERSE SET 3

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
120	X	L2 ↓	1.319	-.108			
		L4 ↓	1.752				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.056	-.432			
		L3 ↓	2.003				
		L1 ↑					
		L3 ↑					
125	X	L2 ↓	1.389	-.040			
		L4 ↓	1.668				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.020	-.471			
		L3 ↓	2.046				
		L1 ↑					
		L3 ↑					
130	X	L2 ↓	1.494	.068			
		L4 ↓	1.577				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	0.970	-.528			
		L3 ↓	2.109				
		L1 ↑					
		L3 ↑					
135	X	L2 ↓	1.497	.064			
		L4 ↓	1.587				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.032	-.459			
		L3 ↓	2.034				
		L1 ↑		15			91-134

DATE: Dec 7/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

9 of 10

2ND SET

R.H. SAUNDERS G.S.

PLOT:

Ac 68.5
20+68.5
Caissons 5&3

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
140	X	L2 ↓	1.505	.069			
		L4 ↓	1.585				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.039	-.446			
		L3 ↓	2.018				
		L1 ↑					
		L3 ↑					
145	X	L2 ↓	1.491	.058			
		L4 ↓	1.594				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.014	-.486			
		L3 ↓	2.069				
		L1 ↑					
		L3 ↑					
150	X	L2 ↓	1.392	-.040			
		L4 ↓	1.690				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.118	-.387			
		L3 ↓	1.975				
		L1 ↑					
		L3 ↑					
155	X	L2 ↓	1.414	-.018			
		L4 ↓	1.668				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.135	-.367			
		L3 ↓	1.953				
		L1 ↑		76			

DATE: Dec 7/68

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

10 of 10

2nd Set

R.H. Saunders G.S.

PLOT:

Arbeiam
20+65.5
Inverse St 3

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
160	X	L2 ↓	1.562	.132			
		L4 ↓	1.516				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.223	-.274			
		L3 ↓	1.855				
		L1 ↑					
		L3 ↑					
	X	L2 ↓					
		L4 ↓					
		L2 ↑					
		L4 ↑					
	Y	L1 ↓					
		L3 ↓					
		L1 ↑					
		L3 ↑					
	X	L2 ↓					
		L4 ↓					
		L2 ↑					
		L4 ↑					
	Y	L1 ↓					
		L3 ↓					
		L1 ↑					
		L3 ↑					
	X	L2 ↓					
		L4 ↓					
		L2 ↑					
		L4 ↑					
	Y	L1 ↓					
		L3 ↓					
		L1 ↑					

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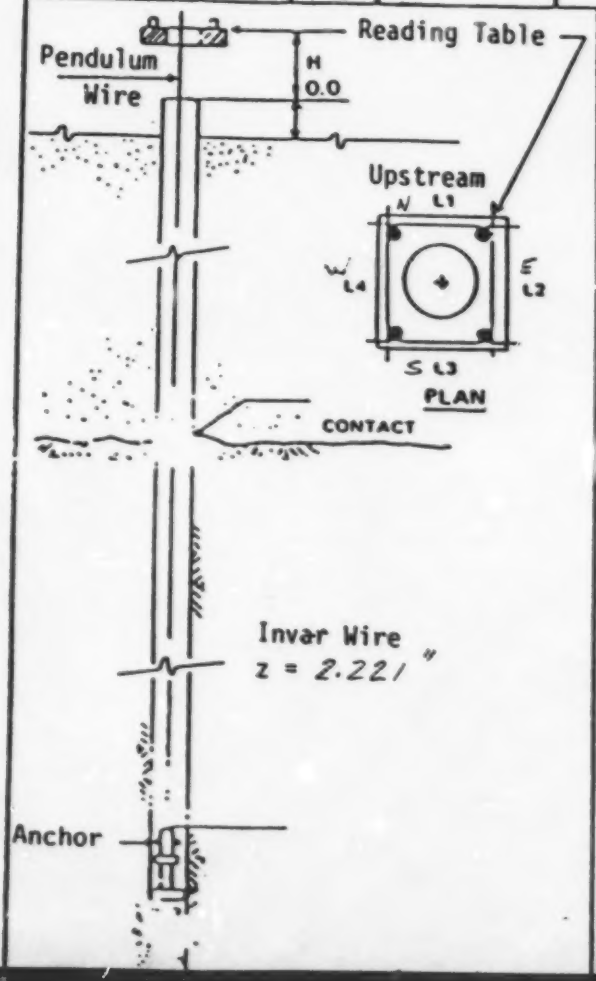
	Inverted Pendulum Datum Readings	Page 1 of 8
DATE: Dec 8/88 TEMP.:		Observer A Marker Beam Chainage 26+15 Elevation
PROJECT: LH. SAUNDERS. G-S.		

Depth (ft)	Axis	Rdg No	Reading Inches	Position	Actual Position	Original Position	Displacement
Reading Table H =	X	L2	1.470	.069	(Px) .069		
		L4	1.607				
		L2					
		L4					
	Y	L1	1.605	-.069	(Py) -.069		
		L3	1.467				
		L1					
		L3					



Position of centre of the reading table relative to the pendulum anchor

$x = \frac{L4 - L2}{2}$ $y = \frac{L3 - L1}{2}$

$\frac{1.607 - 1.470}{2} = .069"$ $\frac{1.467 - 1.605}{2} = -.069"$

Auto centering device

Position of the wire, at various depths relative to the pendulum anchor

$x = \frac{L2 - L4}{2} + Px$

$y = \frac{L1 - L3}{2} + Py$

Table Constant x = 3.095 + .047 = 3.142

y = 3.095 + .047 = 3.142

Wire Diameter .047

DATE: DEC 8/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

2 of 8

A. Adrian
26 + 15
INVERSE SI 2

R.H. SAUNDERS G-S. PLOT:

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
SURFACE	X	L2 ↓	1.377	-.088			
		L4 ↓	1.691				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.495	-.110			
		L3 ↓	1.577				
		L1 ↑					
		L3 ↑					
5	X	L2 ↓	1.298	-.170			
		L4 ↓	1.775				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.432	-.172			
		L3 ↓	1.638				
		L1 ↑					
		L3 ↑					
10	X	L2 ↓	1.273	.193 -.~~354~~			
		L4 ↓	1.796				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.470	-.135			
		L3 ↓	1.602				
		L1 ↑					
		L3 ↑					
15	X	L2 ↓	1.265	-.203			
		L4 ↓	1.808				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.458	-.147			
		L3 ↓	1.614				
		L1 ↑					

+.065
-.069

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DATE: Oct. 8/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

3 OF 8

R. H. SAUNDERS G-S. PLOT:

Ac & Beam
Oct 15
INVERTED SET

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
20	X	L2	1.213	-.255			
		L4	1.860				
		L2					
		L4					
	Y	L1	1.371	-.234			
		L3	1.700				
		L1					
		L3					
25	X	L2	1.132	-.336			
		L4	1.942				
		L2					
		L4					
	Y	L1	1.248				
		L3	1.842	-.366			
		L1					
		L3					
30	X	L2	1.097	-.440			
		L4	1.976				
		L2					
		L4					
	Y	L1	1.131	-.474			
		L3	1.940				
		L1					
		L3					
35	X	L2	1.099	-.370			
		L4	1.976				
		L2					
		L4					
	Y	L1	1.072	-.535			
		L3	2.004				
		L1		80			91-134

+.069
-.069

DATE: Oct 8/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

8 of 8

A. & Brian
26 & 15
Inverse Sez

R. H. SAUNDERS G-S. PLOT:

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
40	X	L2 ↓	1.088	-.379			
		L4 ↓	1.983				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.000	-.607			
		L3 ↓	2.075				
		L1 ↑					
		L3 ↑					
45	X	L2 ↓	1.138	-.329			
		L4 ↓	1.934				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.011	-.593			
		L3 ↓	2.059				
		L1 ↑					
		L3 ↑					
50	X	L2 ↓	1.203	-.263			
		L4 ↓	1.867				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.085	-.522			
		L3 ↓	1.991				
		L1 ↑					
		L3 ↑					
55	X	L2 ↓	1.253	-.212			
		L4 ↓	1.815				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.198	-.406			
		L3 ↓	1.871				
		L1 ↑		81			

+.069
+.069

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DATE: Dec 8/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

5 OF 8

R.H. SAUNDERS G.S. PLOT:

R & BRIAN
26+15.
WATER SEE

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
60	X	L2 ↓	1.354	-.115			
		L4 ↓	1.722				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.283	-.321			
		L3 ↓	1.787				
		L1 ↑					
		L3 ↑					
65	X	L2 ↓	1.383	-.082			
		L4 ↓	1.684				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.348	-.256			
		L3 ↓	1.721				
		L1 ↑					
		L3 ↑					
70	X	L2 ↓	1.400	-.064			
		L4 ↓	1.666				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.412	-.193			
		L3 ↓	1.659				
		L1 ↑					
		L3 ↑					
75	X	L2 ↓	1.397	-.070			
		L4 ↓	1.674				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.434	-.171			
		L3 ↓	1.637				
		L1 ↑					
		L3 ↑					

-.063
-.063

82

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DATE: Oct 8/00

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

6 OF 8

R.H. SAWDOCS G.J. PLOT:

At Equal
26.15
Middle Set

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
80	X	L2	1.381	-.057			
		L4	1.693				
		L2					
		L4					
	Y	L1	1.436	-.169			
		L3	1.636				
		L1					
		L3					
85	X	L2	1.358	-.109			
		L4	1.714				
		L2					
		L4					
	Y	L1	1.460	-.145			
		L3	1.611				
		L1					
		L3					
90	X	L2	1.349	-.118			
		L4	1.722				
		L2					
		L4					
	Y	L1	1.456	-.149			
		L3	1.615				
		L1					
		L3					
95	X	L2	1.369	-.098			
		L4	1.702				
		L2					
		L4					
	Y	L1	1.443	-.160			
		L3	1.625				
		L1		83			

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DATE: Dec 8/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

7 OF 8

A. & BEAM.
26 + 15
INVERTED 512

R.H. Saunders G-S.

PLOT:

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
100	X	L2	1.358	-.108			
		L4	1.712				
		L2					
		L4					
	Y	L1	1.457	-.147			
		L3	1.613				
		L1					
		L3					
105	X	L2	1.393	-.073			
		L4	1.676				
		L2					
		L4					
	Y	L1	1.501	-.103			
		L3	1.568				
		L1					
		L3					
110	X	L2	1.364	-.103			
		L4	1.708				
		L2					
		L4					
	Y	L1	1.468	-.137			
		L3	1.604				
		L1					
		L3					
115	X	L2	1.365	-.099			
		L4	1.702				
		L2					
		L4					
	Y	L1	1.476	-.130			
		L3	1.597				
		L1					
		L3					

+.069
-.069

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DATE: Oct 6/88

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

8 of 8

R.H. SAUNDERS G-S. PLOT:

A. & Brian
26 x 15
INVERSE SEQUENCE

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
120	X	L2	1.385	-.084			
		L4	1.690				
		L2					
		L4					
	Y	L1	1.461	-.145			
		L3	1.613				
		L1					
		L3					
	X	L2					
		L4					
		L2					
		L4					
	Y	L1					
		L3					
		L1					
		L3					
	X	L2					
		L4					
		L2					
		L4					
	Y	L1					
		L3					
		L1					
		L3					
	X	L3					
		L4					
		L2					
		L4					
	Y	L1					
		L3					
		L1					

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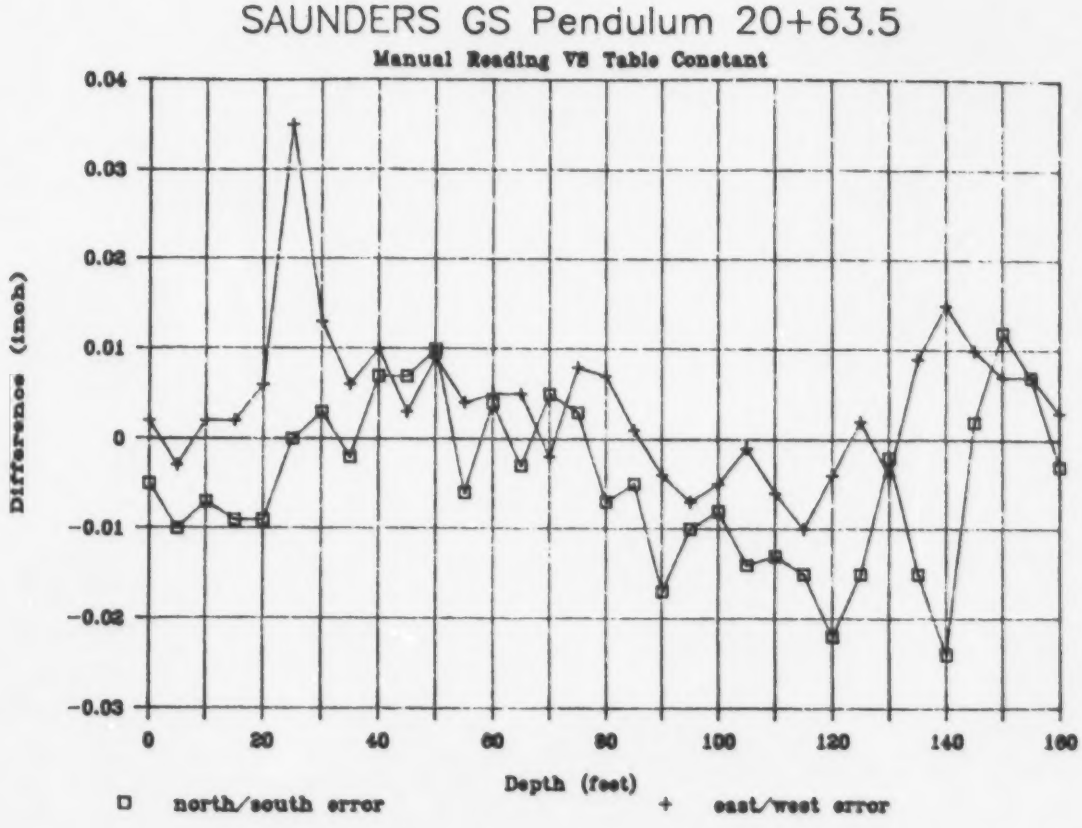
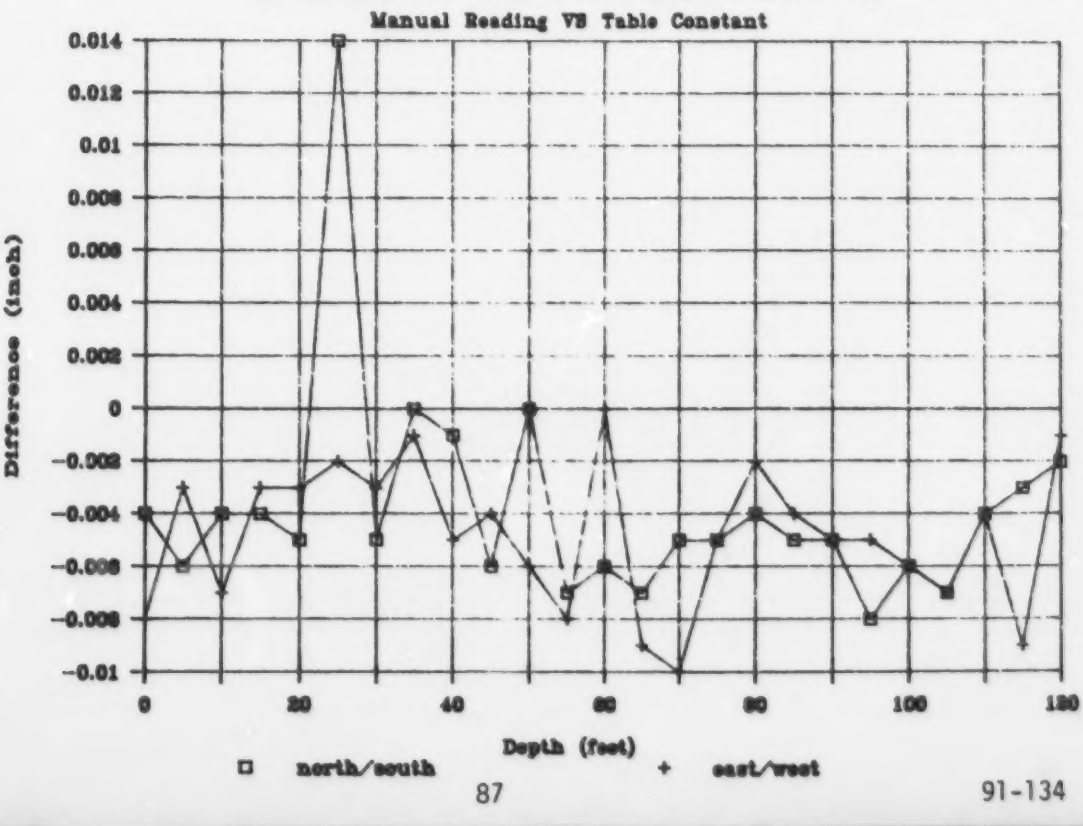
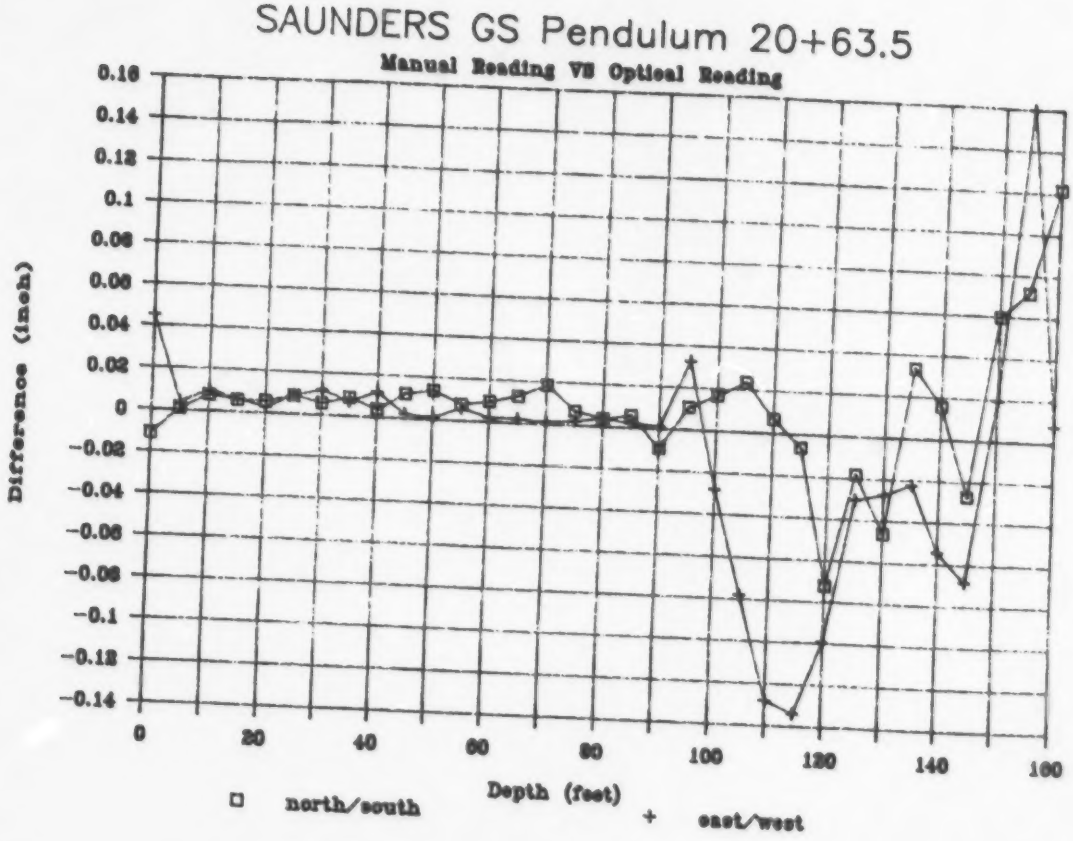
-.069

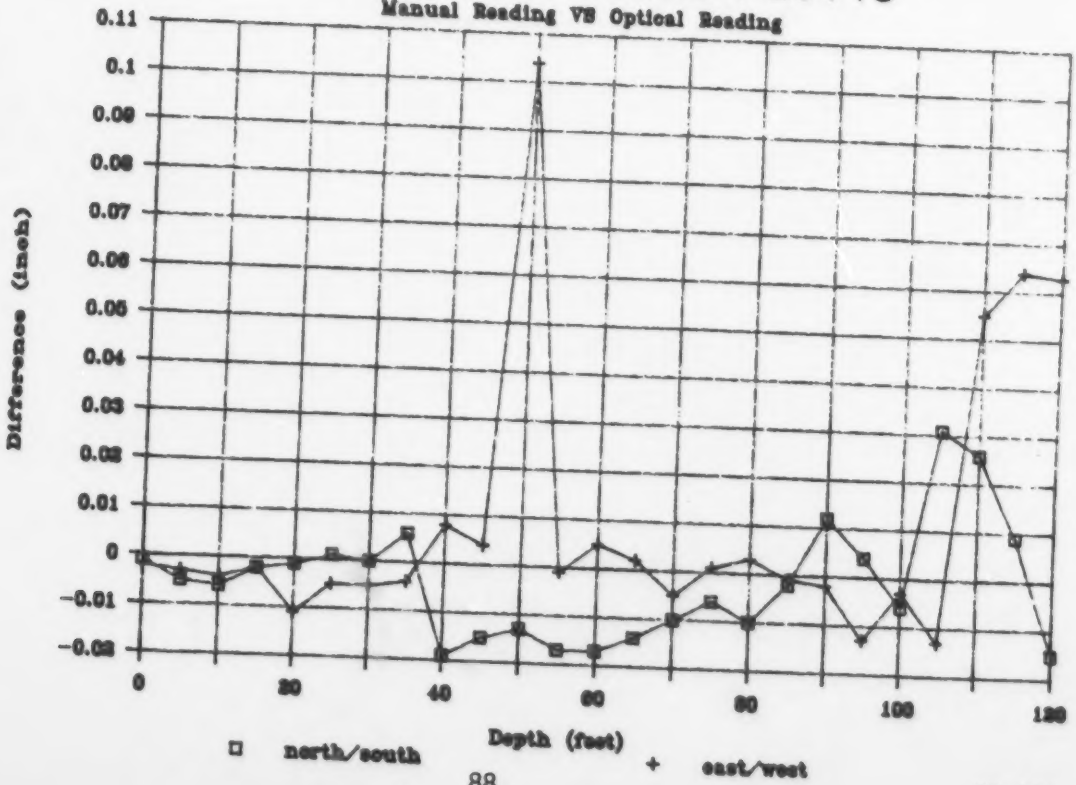
APPENDIX F

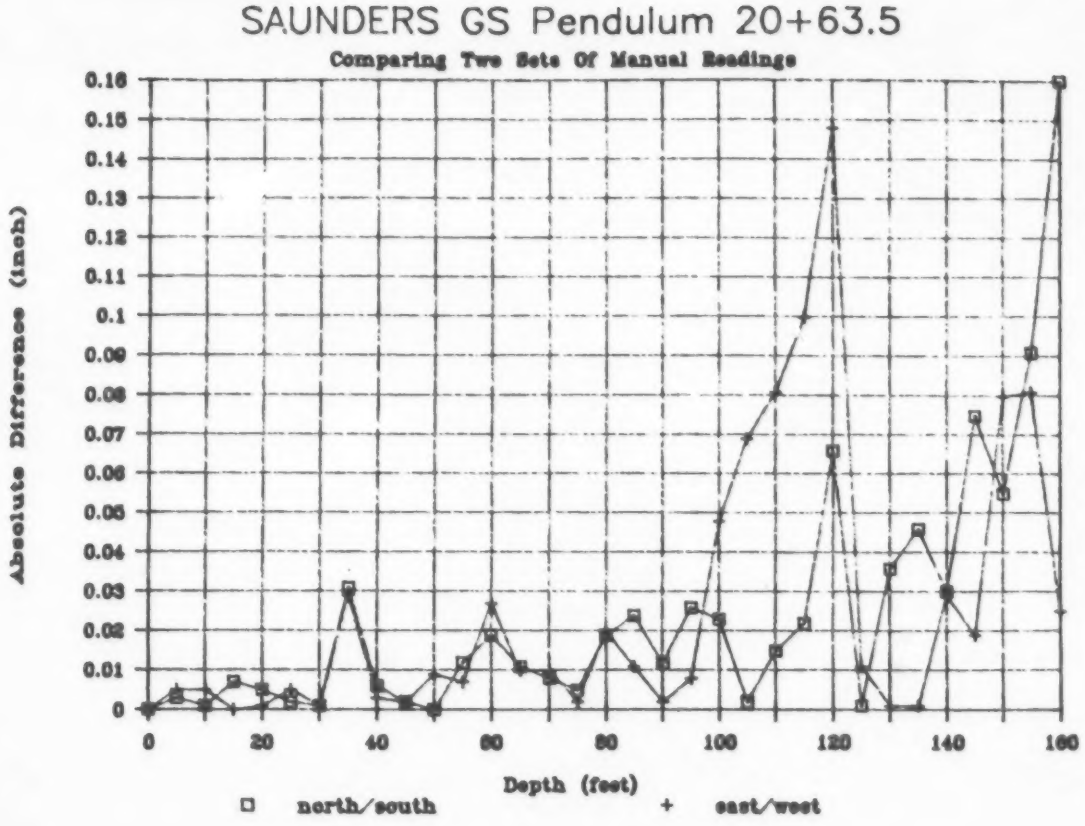
Comparison of Autocentering Readings
at R.H. Saunders GS

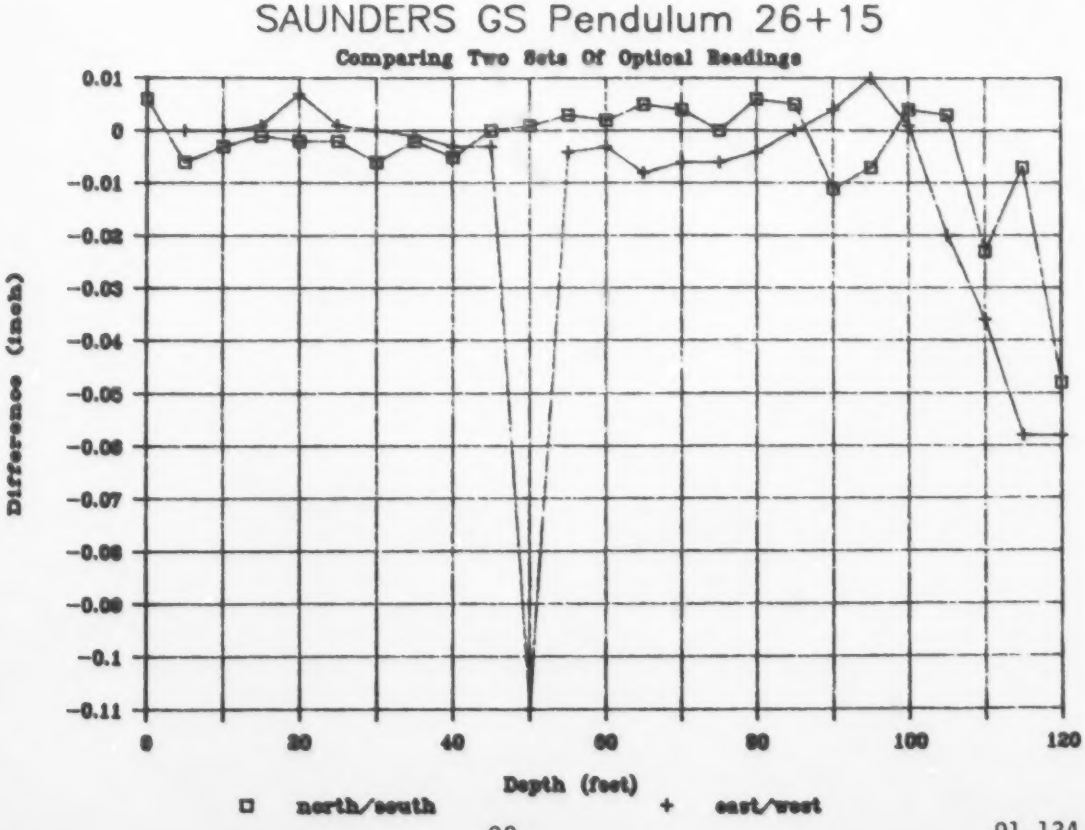

SAUNDERS GS Pendulum 20+63.5
Manual Reading VS Table Constant
Difference (inch)
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
0
20
40
60
80
100
120
140
160
Depth (feet)
north/south error
east/west error


SAUNDERS GS Pendulum 26+15
Manual Reading VS Table Constant
Difference (inch)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
0
20
40
60
80
100
120
Depth (feet)
north/south
east/west


SAUNDERS GS Pendulum 20+63.5
Manual Reading VS Optical Reading
Difference (inch)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
0
20
40
60
80
100
120
140
160
Depth (feet)
north/south
east/west

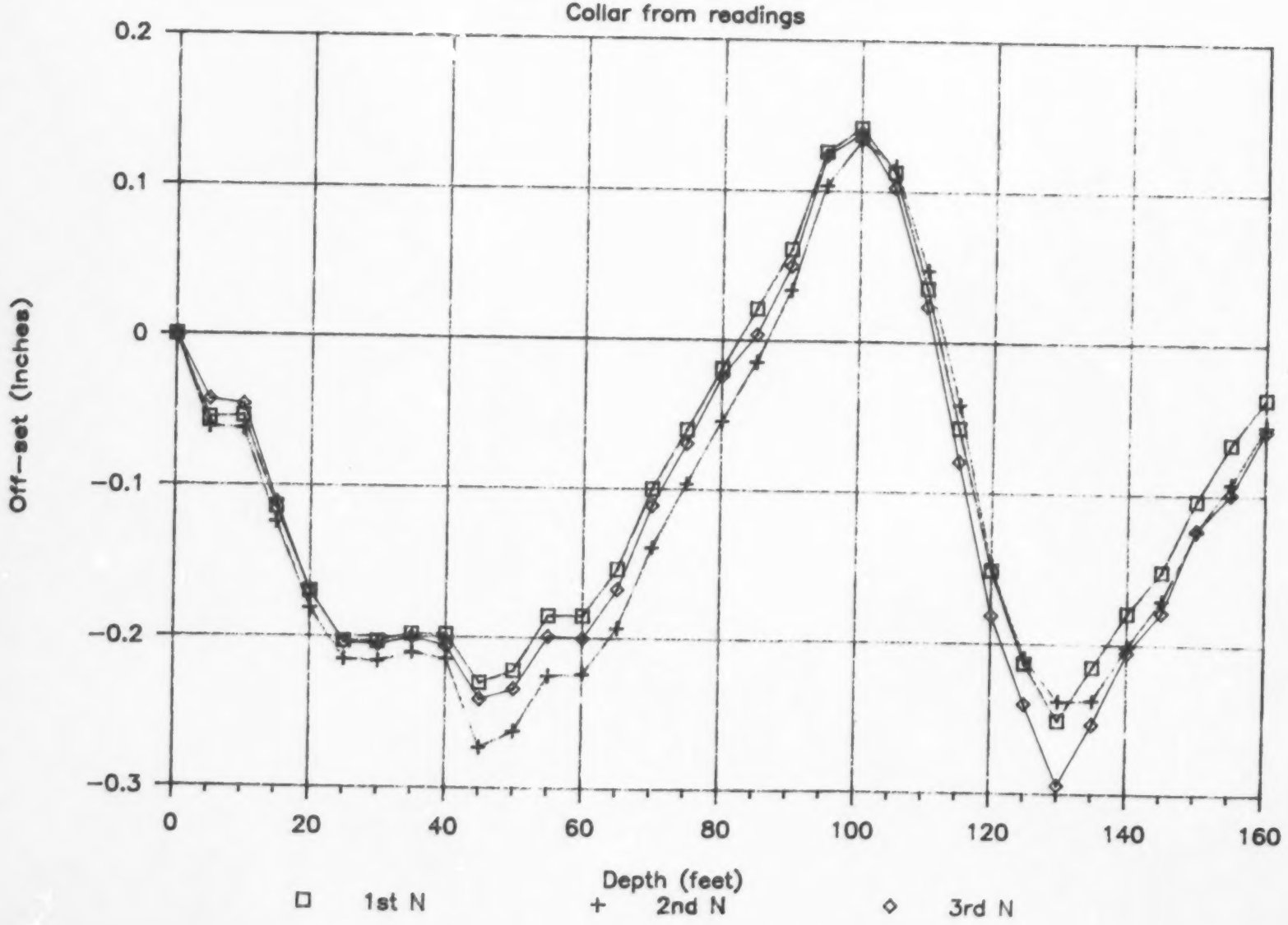

SAUNDERS GS Pendulum 26+15
Manual Reading VS Optical Reading
Difference (inch)
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
0
20
40
60
80
100
120
Depth (feet)
north/south
east/west


SAUNDERS GS Pendulum 20+63.5
Comparing Two Sets Of Manual Readings
Absolute Difference (inch)
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
20
40
60
80
100
120
140
160
Depth (feet)
north/south
east/west


SAUNDERS GS Pendulum 26+15
Comparing Two Sets Of Optical Readings
Difference (inch)
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.1
-0.11
0
20
40
60
80
100
120
Depth (feet)
north/south
east/west

20635. gps
20635@5. pic

Optical Reference



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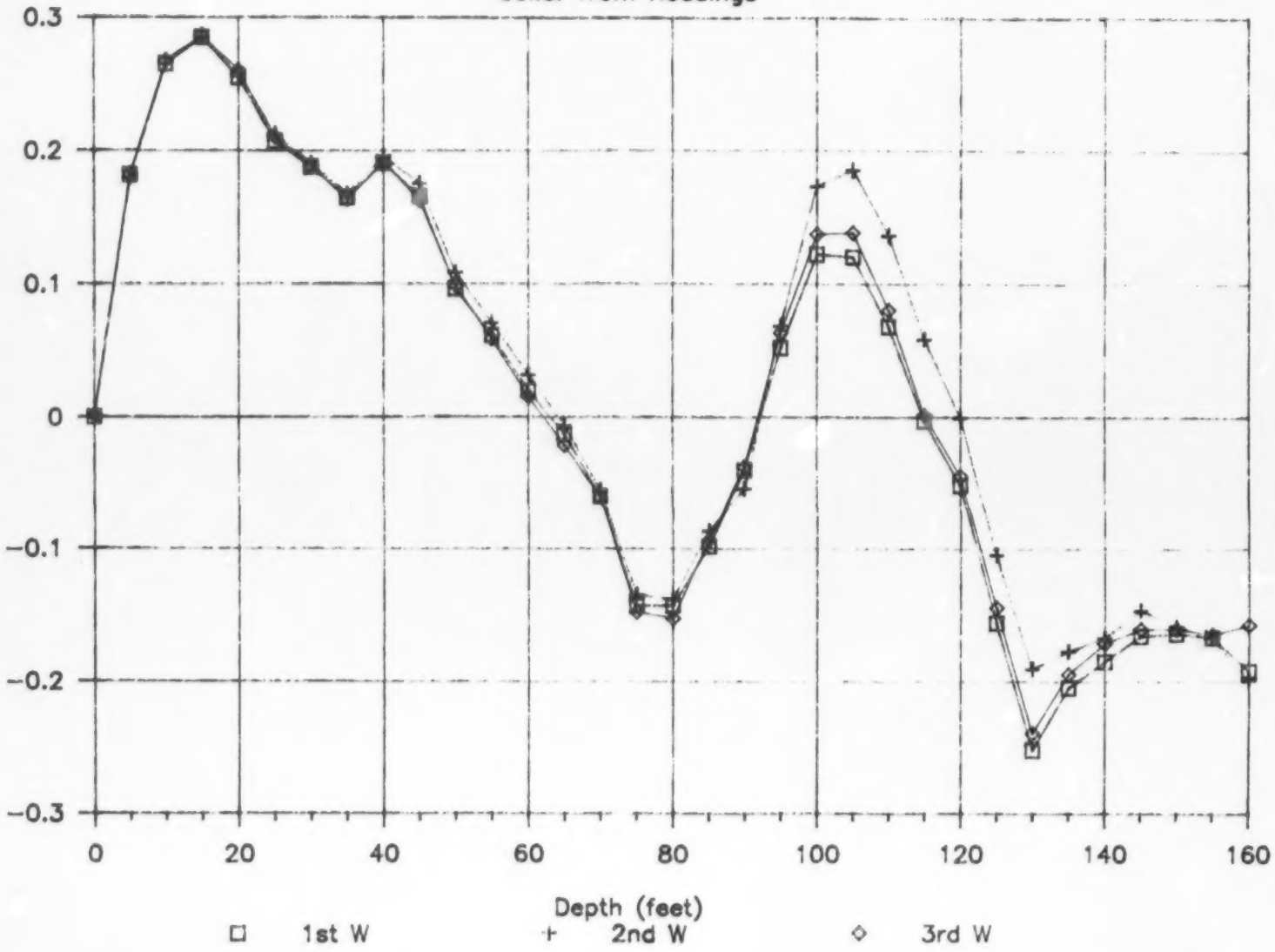
20635.gpf
20635007.PIC

Optical Reference

Collar from Readings



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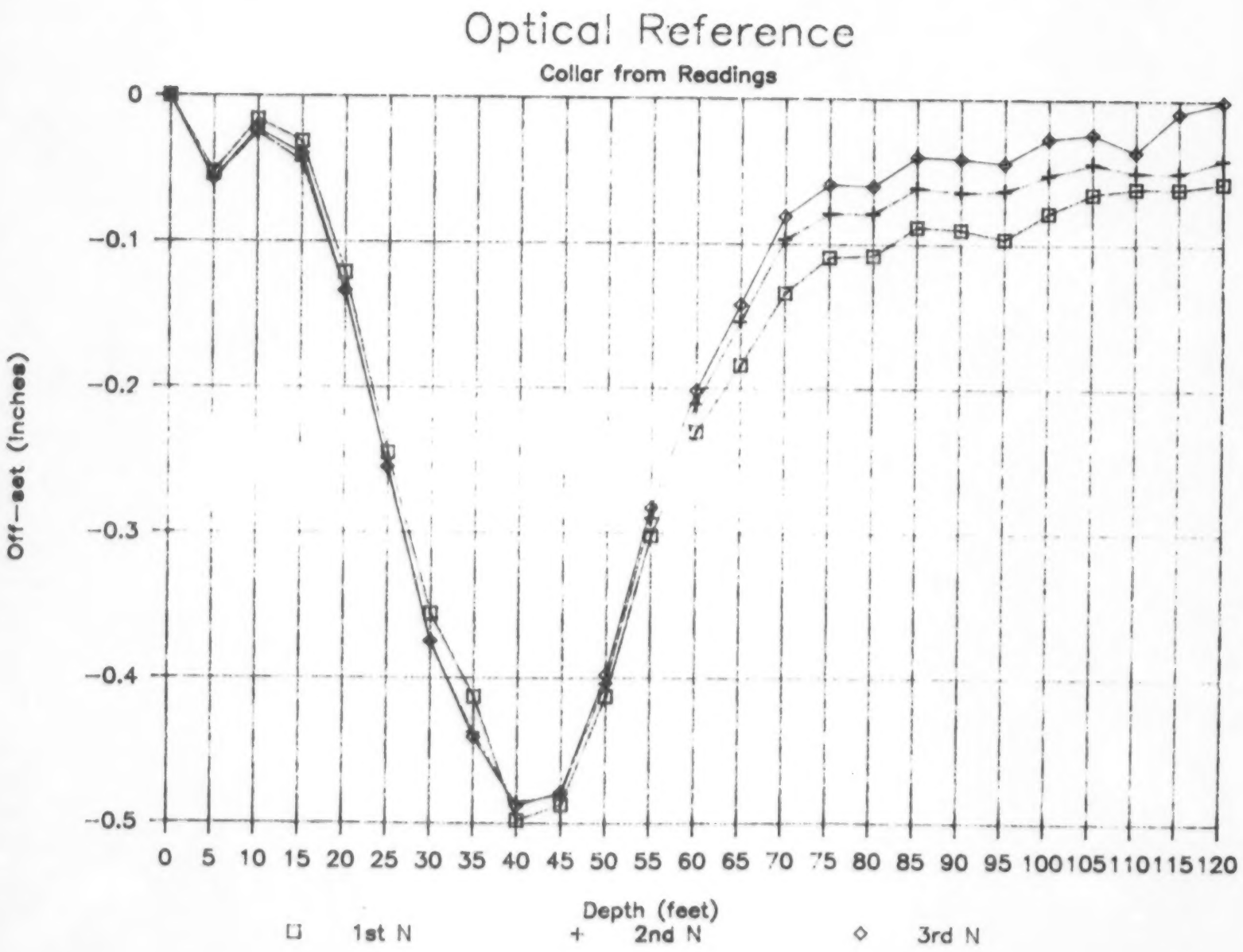
2615. SP3
2615-03. PIC



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2615. SP4

2615-04. PIC

Optical Reference